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Report of Autumn General Meeting 1960 269

Pre-refining of blast-furnace iron
E. Davies 271

Application of flow research to industrial furnaces
H. Boenecke 283

Strain ageing and the fatigue limit of steel
J. C. Levy and S. L. Kanitkar 296

Influence of local temperature increases on fretting corrosion of mild steel
R. B. Waterhouse 301

Solubility of silicon nitride in ferrite
R. Rawlings and P. M. Robinson 306

Application of a digital computer to pre-operational problems
H. I. A. Archibald 309

Sinter plant assessment trials
J. McKelvie and G. Wilson 313

News 325 Abstracts 329

A full list of contents is given on the Title Page (see page 71 of the Advertisement Section)

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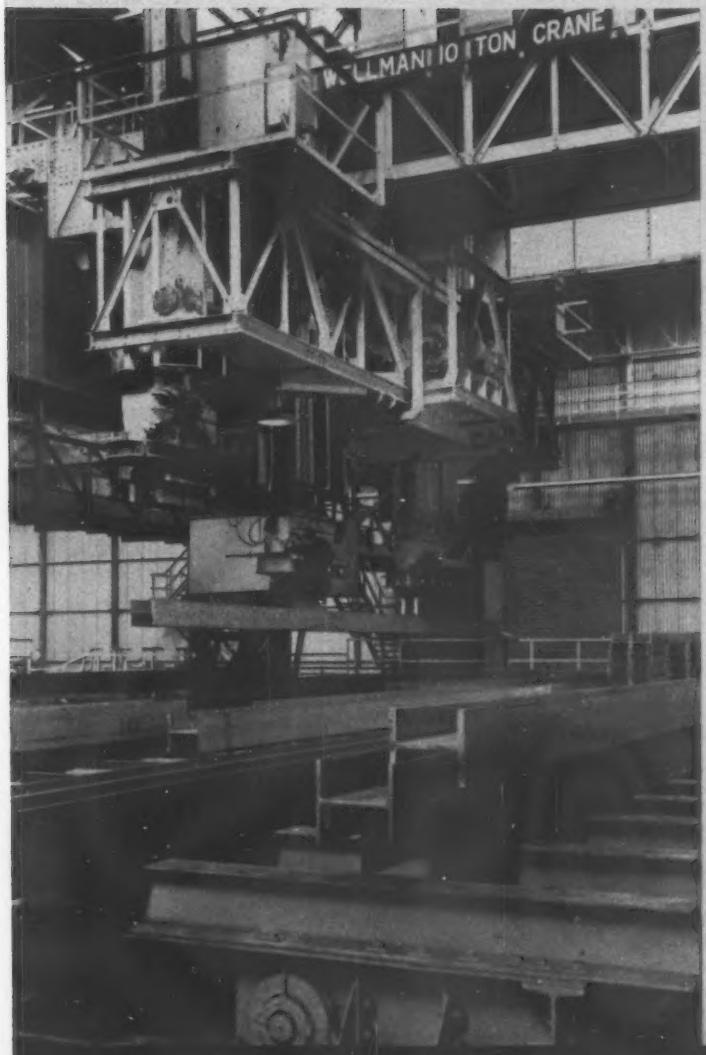

One of two Wellman 10-ton Electric Overhead Travelling Magnet Beam Piling Cranes specially designed and constructed to pick up beams and stack them in neat piles suitable for loading into bolster wagons.

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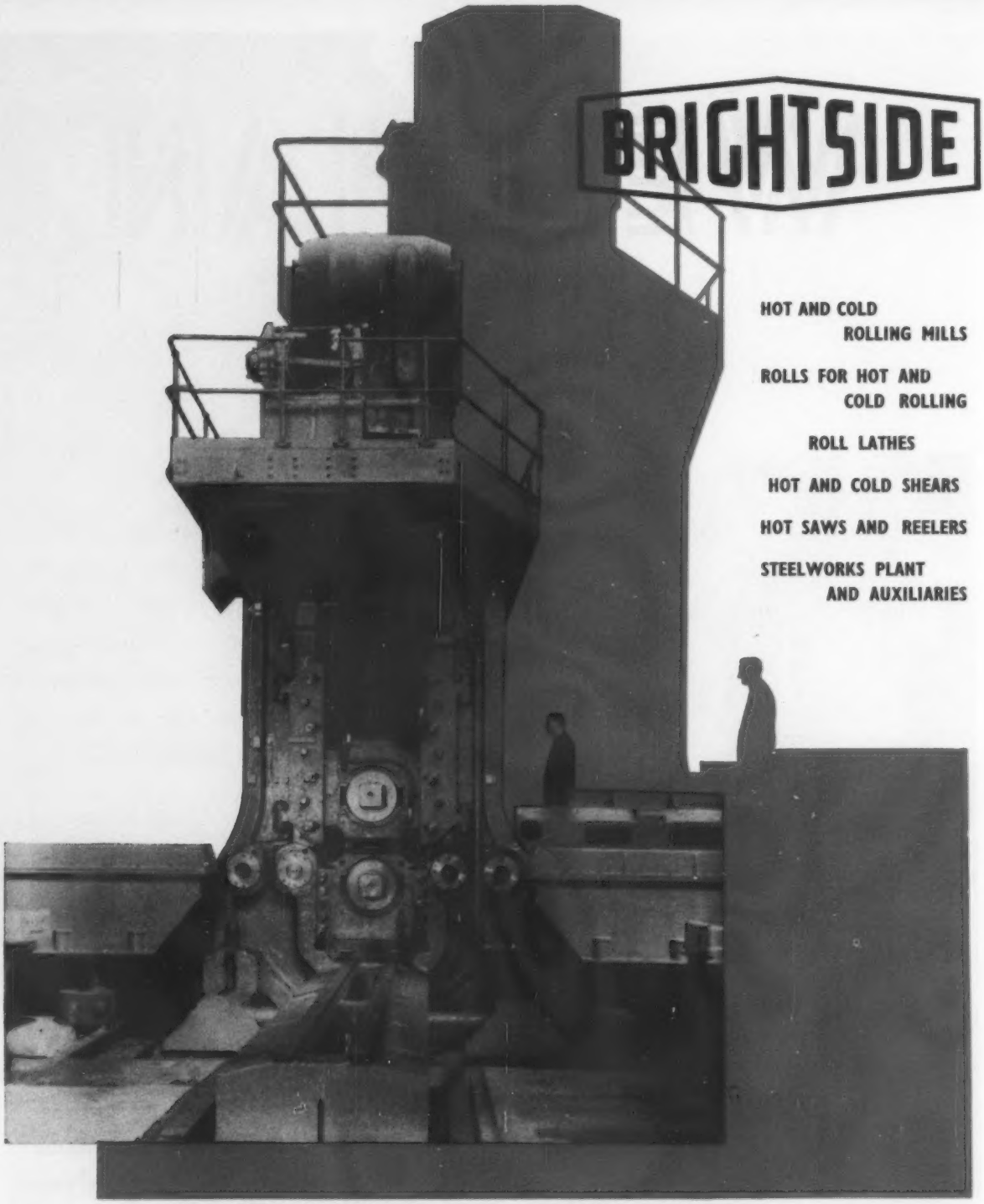

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There is only one person properly able to judge the merits of one electrode against another—the user. If, then, you know of someone who has bought and tried AGL graphite electrodes, ask him.

He will tell you that their performance is excellent; that their taper-threading gives stronger joints; that they cut down repair time—drastically; and that they are backed by a service as quick as it is reliable.

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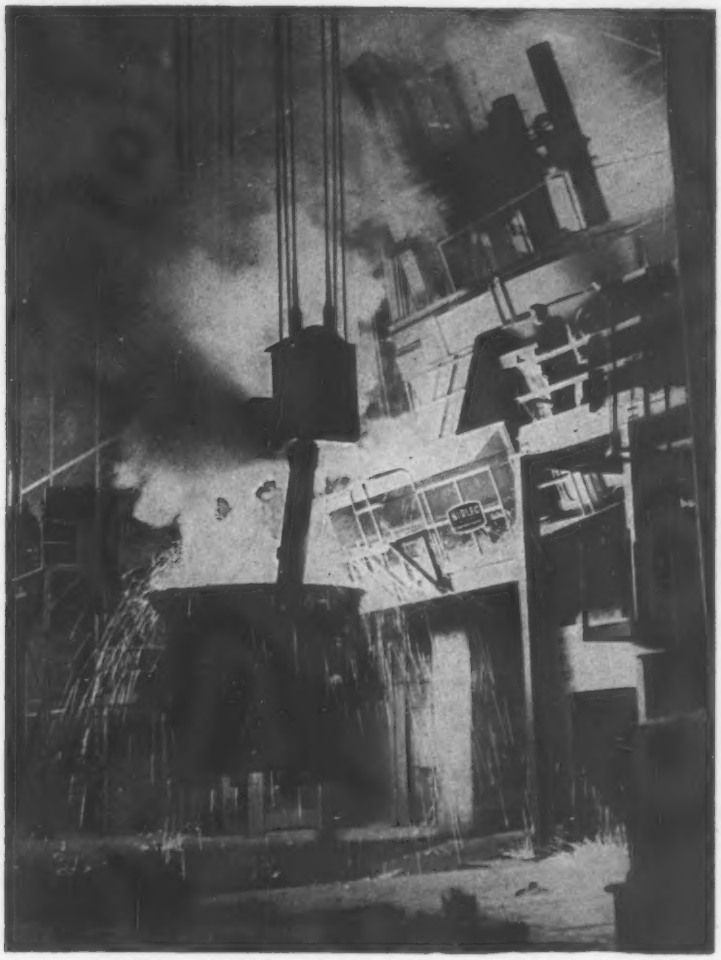

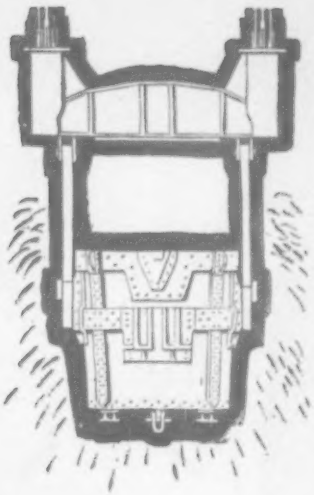

ELECTRIC TONNAGE STEEL

Tapping one of the three electric arc furnaces installed in the new melting shop at Brymbo Steel Works Limited, Wrexham.

The three 16ft. electric arc furnaces installed at Brymbo Steel Works Limited, each rated at 12,500 kVA, have replaced the company's open hearth plant, an important departure from conventional practice. Though ordered from Birlec Limited before the amalgamation of their melting interests with those of Efco Limited, these units are typical of the Birlefco range of arc furnaces. Between them, the constituent companies have built more than 600 arc furnaces throughout the world, including every British installation exceeding 30 tons capacity.

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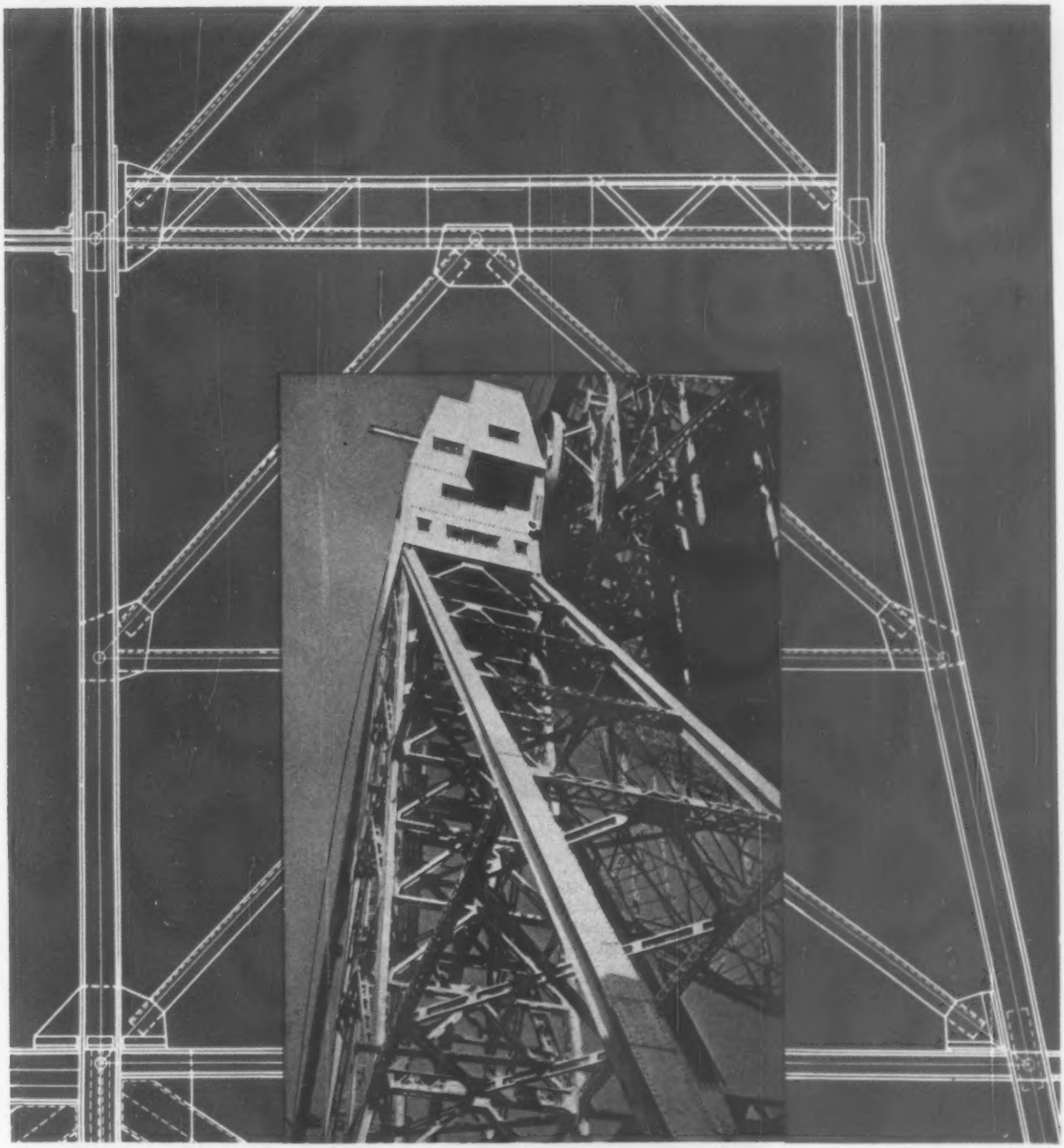
Refractories Ltd
Mr BLAIN
TAKE A LOOK AT THIS!
Record Blast Furnace Campaign with new Refractory
The first blast furnace in the United Kingdom to use a British super-duty firebrick for its complete stack lining has just finished its initial campaign. This is the Queen Bess furnace of the Appleby-Frodingham Steel Company and the stack was lined with M.R.2 bricks.
During its campaign the furnace produced 920,700 tons of iron involving a throughput of 2,450,000 tons of burden and 750,000 tons of coke. Throughout the entire campaign the burden consisted of 100% sinter. The tonnage handled by this furnace on such a practice is a record for the Appleby-Frodingham organisation.
AND THIS!
RECORD BROKEN
United Steel's "Queen Victoria" blast furnace at Appleby-Frodingham has beaten the record set up only a month ago by the same company's "Queen Bess" furnace—please see our release of 10th June. For the first time a British blast furnace operating with 100% sinter burden has produced over 1m. tons of iron. The campaign is continuing and the stack lining is in excellent condition. As in the "Queen Bess", the stack is lined with M.R.2 super-duty firebricks manufactured by Morgan Refractories Ltd., a subsidiary of The Morgan Crucible Company Ltd. The campaign has now lasted 112 weeks. During this period the "Queen Victoria" has been charged with 2,570,000 tons of sinter containing 36% iron, 40,000 tons of scrap and 820,000 tons of coke. 26 cwt. of slag is tapped for each ton of metal produced, so that the liquid output of the furnace so far this campaign is 2¼m. tons.
Issued by The Morgan Crucible Co. Ltd, Public Relations Dept. (Battersea 8822) on behalf of Morgan Refractories Ltd.
NOW 1¼m.! (JAN. '61)
171A



Radio telescope at Jodrell Bank built by United Steel Structural Company

Bowl diameter—250 *ft.*

Height of towers—180 *ft*

Weight of structural steelwork—1,800 *tons*

Consulting engineers: Husband & Company

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are supplied by Distington Engineering Company Limited to many steelworks. The Distington's foundry has the highest output of any ingot mould foundry in Europe, and specialises in producing ingot moulds, bottom plates and slag ladles. It can handle castings up to 120 tons in weight.

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WORKINGTON, CUMBERLAND

A subsidiary of The United Steel Companies Limited

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Chromium	·01	·015
Copper	·03	·04
Arsenic	·015	·02
Tin	·015	·02
Vanadium	·02	·04
Molybdenum	*below* ·01	
Lead	*below* ·01	
Cobalt	·005	·008
Antimony	*below* ·01	
Tungsten	*below* ·01	
Titanium	*below* ·01	

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April, 1961

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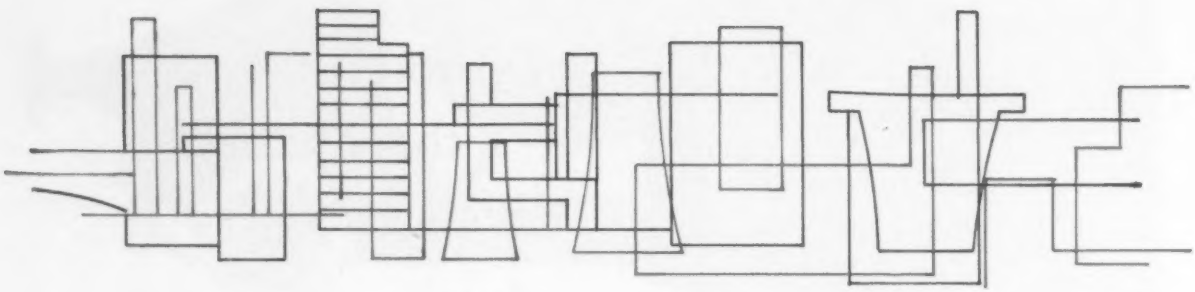

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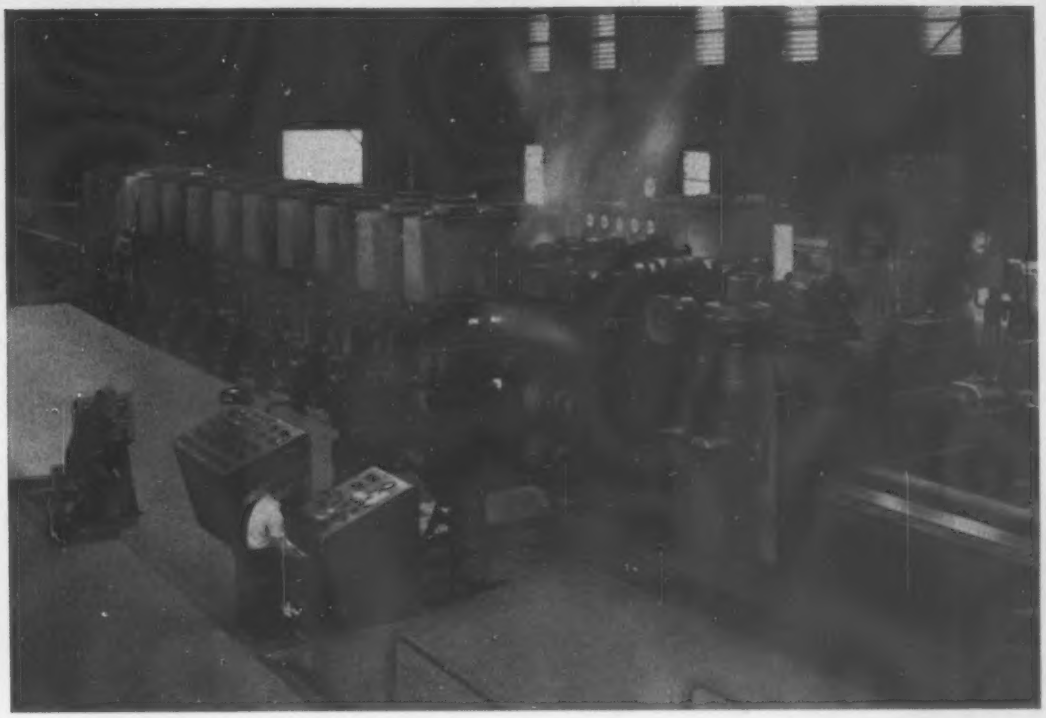

SENDZIMIR PLANETARY HOT ROLLING MILL

BUILT BY **ROBERTSON**

FOR MESSRS. J. J. HABERSHON & SONS LTD., ROTHERHAM
BY WHOSE COURTESY THIS PHOTOGRAPH APPEARS

This mill is designed to produce hot rolled strip up to 15 in. wide and as thin as ·048 from slabs 1¾ in. thick in mild, high carbon and stainless steels.

The mill consists essentially of feed rolls, planetary roll assembly and a final two-high planishing mill followed by coiling equipment.

Nominal output is 10 tons per hour which has already been considerably exceeded.

Surface finish is fully up to the standard required for subsequent cold rolling.

This is the second Planetary Mill in Great Britain both of which have been built by Robertson.

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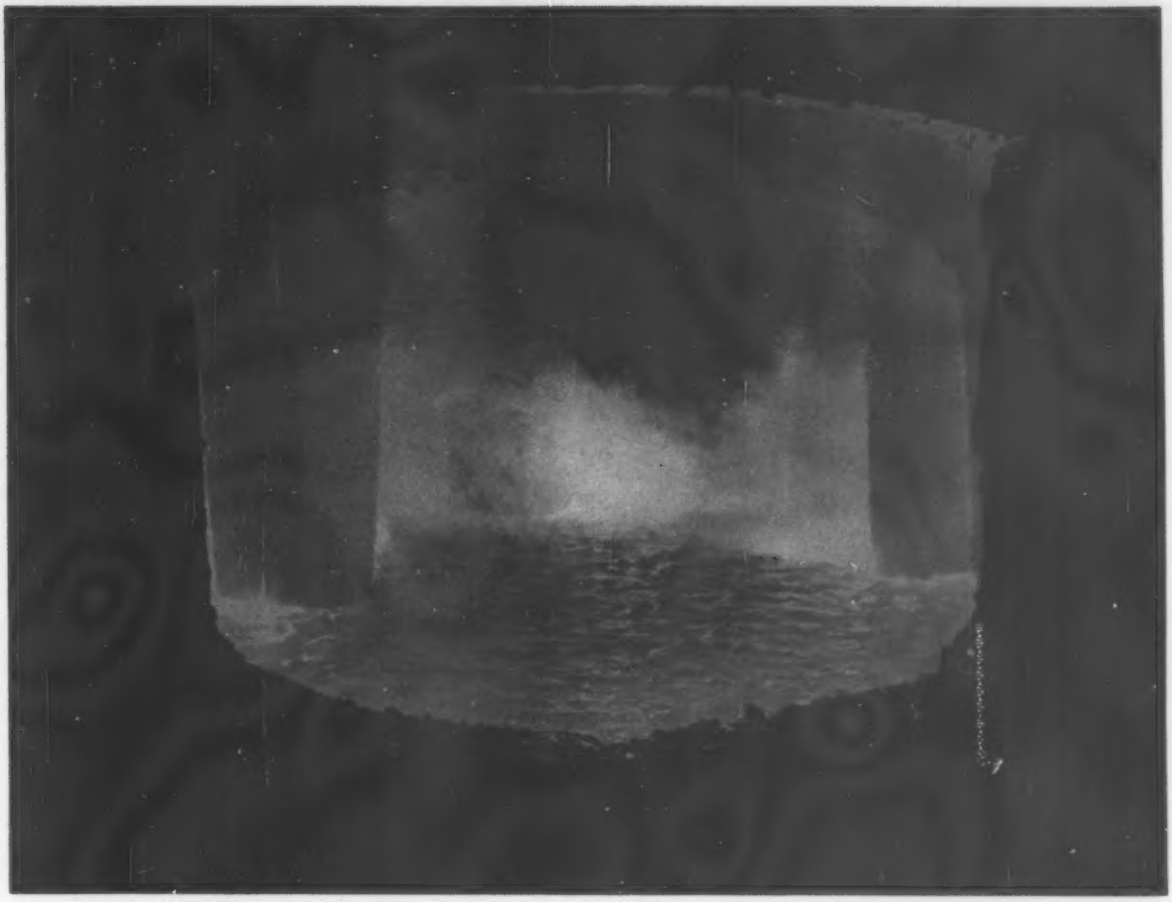

By courtesy of Thomas Firth & John Brown Limited

Lungs for an inferno

Truly through its electrodes an arc furnace draws its breath of electric power. On the high quality and dependability of these lungs rest so much the burden of ensuring the smooth efficiency and economy of the arc furnace as a steel-melting unit. The excellent properties of 'Acheson' graphite electrodes are a sure guarantee of first-rate performance

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We do not supply drivers or manufacture cars; but long before the question of driving arises, GKN is co-operating with the motor industry on a very large scale indeed. Machines for toolmaking; automated welding and paint-spraying plant; forgings of every description; fastenings without end—over 80 companies of the GKN Group are inextricably, and very happily, involved in travel and transport. The GKN Group includes Europe's largest makers of pressed steel vehicle wheels and Britain's biggest producers of chassis frames; and there are GKN companies making auto body panel assemblies, cylinder blocks, con. rods, crankshafts. Certainly, without us, there would be very little driving—from either seat.

GKN

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Speed control of Electric Motors

'Variable' speed may involve two or three (or more) speed steps or infinitely variable (stepless) speed control. It is this latter type which is considered below. Of the many advantages of electric drives, the opportunity offered for infinitely variable speed control is outstanding. Unfortunately this advantage is not used as much as it might be to increase the speed of working, and to improve productivity and quality.

Principal Factors Affecting Choice of Drive

(a) First cost, (b) Efficiency, (c) Speed range, (d) Regulation, (e) Power-to-weight ratio, (f) Availability of supply, (g) Maintenance and reliability, (h) Change in power and torque over the speed range, (i) Simplicity of control gear, (j) Effect of variation in supply, (k) Power factor, (l) Characteristics of the load, (m) Operational environment, (n) Braking requirements.

This list is not meant to be all-embracing, for there well may be factors not mentioned which could prove conclusive in the choice of a drive.

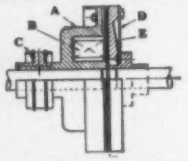
The following are some methods of obtaining infinitely variable speeds:

Alternating Current Motors

The vast majority of electric drives in use today employ A.C. motors. Although not quite so flexible as D.C. motors in the matter of speed control, there are available many types which give a large measure of speed variation.

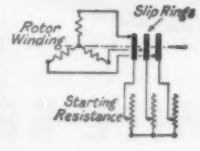
INDUCTION MOTORS. Although the squirrel-cage motor is essentially a constant-speed machine, it is much used for stepless variable speed drives with one of the following types:

(a) Eddy-current coupling,
(b) Ferro-magnetic particle coupling,
(c) Mechanical drives, e.g. belt drives and friction drives,
(d) Hydraulic variable speed drives.



A, Magnet body; B, Magnet coil; C, Collector gear; D, Spring plate; E, Armature.

SLIP-RING MOTOR. The slip-ring motor, which costs more than the squirrel-cage motor, can be varied in speed by means of the resistors in the rotor circuit used for starting. The amount of resistance in circuit can be varied in steps by means of different forms of control gear operated by hand, push-button or automatically controlled contactors.



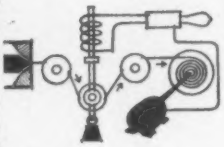
A.C. COMMUTATOR MOTORS. These are three-phase induction motors provided with additional windings which, through a commutator and brushes, permit speed adjustment in either direction below and above synchronous speed. The brush gear can be automatically controlled so as to vary the speed according to a known programme or cycle of operation such as in spinning frames. The Schrage and similar motors are refinements of this type.

Ward-Leonard System

In this system the armature of a D.C. motor is supplied at variable voltage from a separate generator. The generator may be driven by an A.C. or D.C. motor directly coupled to it and to an exciter which supplies the field windings of the generator and main motor. By means of a potentiometer resistance, with mid-point connected to one terminal of the generator field windings, the generator voltage may be varied from maximum to zero.

Electronic Motor Control

Motor speeds can be controlled accurately by electronic methods. Such drives can respond in any desired manner to variations in one or more variables and several drives can be interlocked so that their speeds are always in the same ratio. A typical application is on several separate conveyors. The system can be speeded up or slowed down from a 'master' controller, but for 'running in' purposes the speed of each drive can be individually regulated. Electronic speed control has been successfully applied where human control is not possible, e.g. in register control. In this example print must always be placed at exact positions on packaging material. The sketch shows electronic control of wire tension in drawing operations.



Direct Current Motors

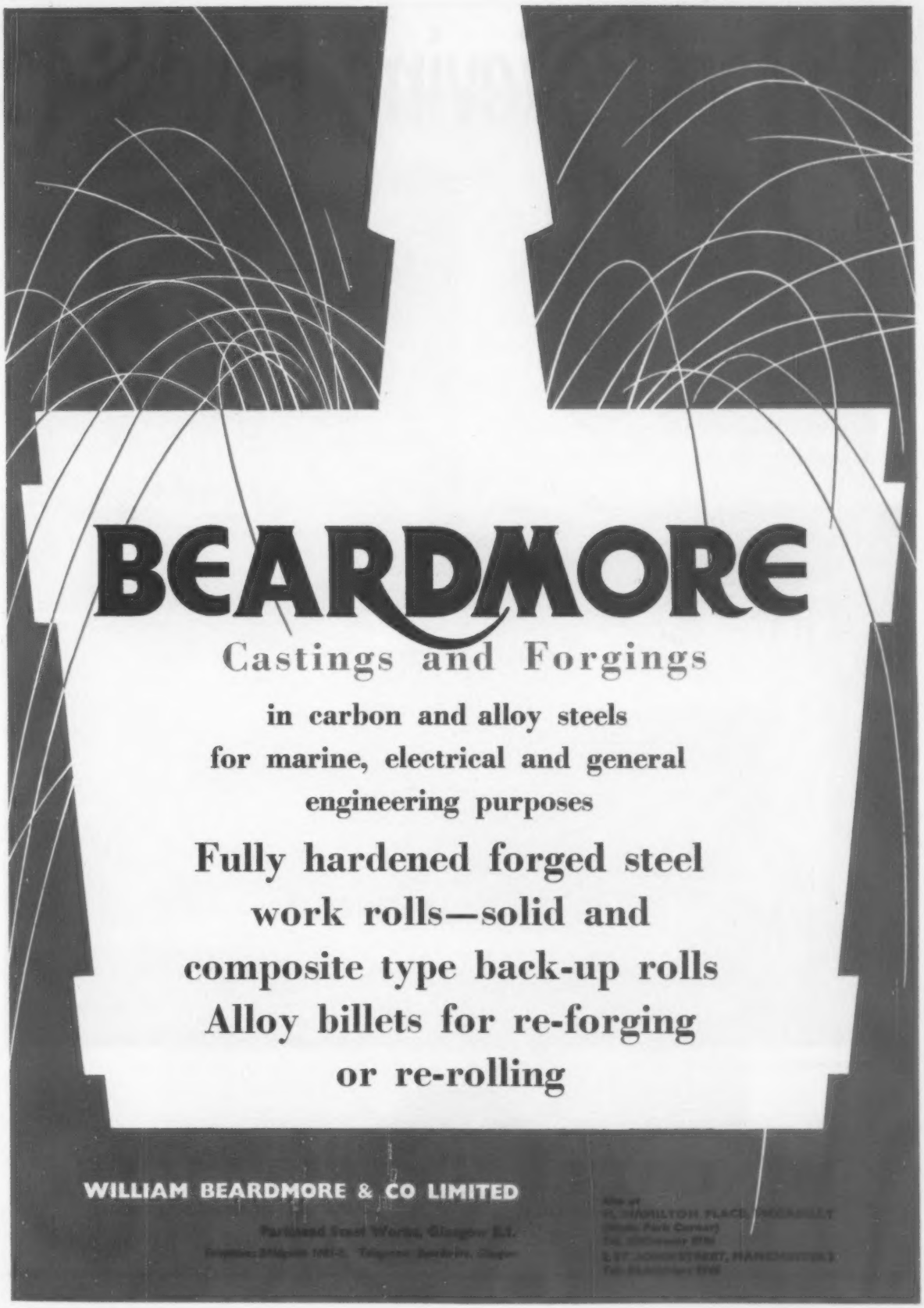
While it is unlikely that a mains supply of D.C. will be available, the striking advantages of D.C. motors sometimes make it worth while installing a rectifier, e.g. a motor-generator set, a mercury-arc or a semi-conductor. The speed of D.C. motors is easily controlled by inserting a resistance in series with the motor. Although this can result in a certain amount of wasted electricity, the benefits derived will often heavily outweigh such losses.

For further information get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2. Telephone: TEMple Bar 9434.

Excellent reference books on electricity and productivity (8/6 each, or 9/- post free) are available —'Electric Motors and Controls' is an example.

E.D.A. also have available on free loan in the United Kingdom a series of films on the industrial uses of electricity. Ask for a catalogue.

CUT HERE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Capable of taking loads up to 250 tons,
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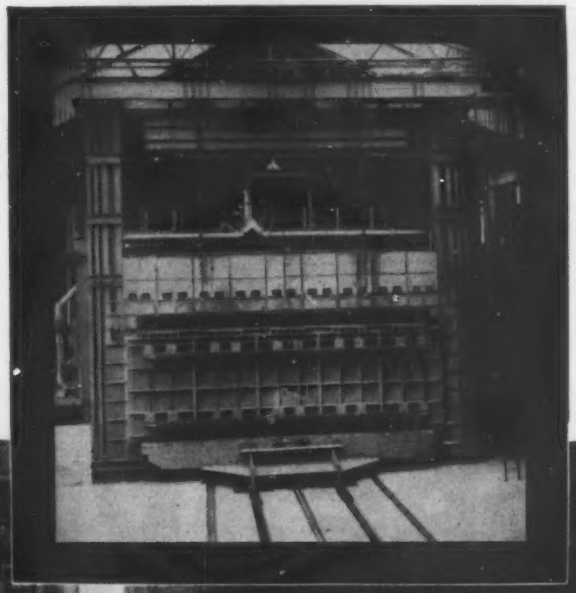
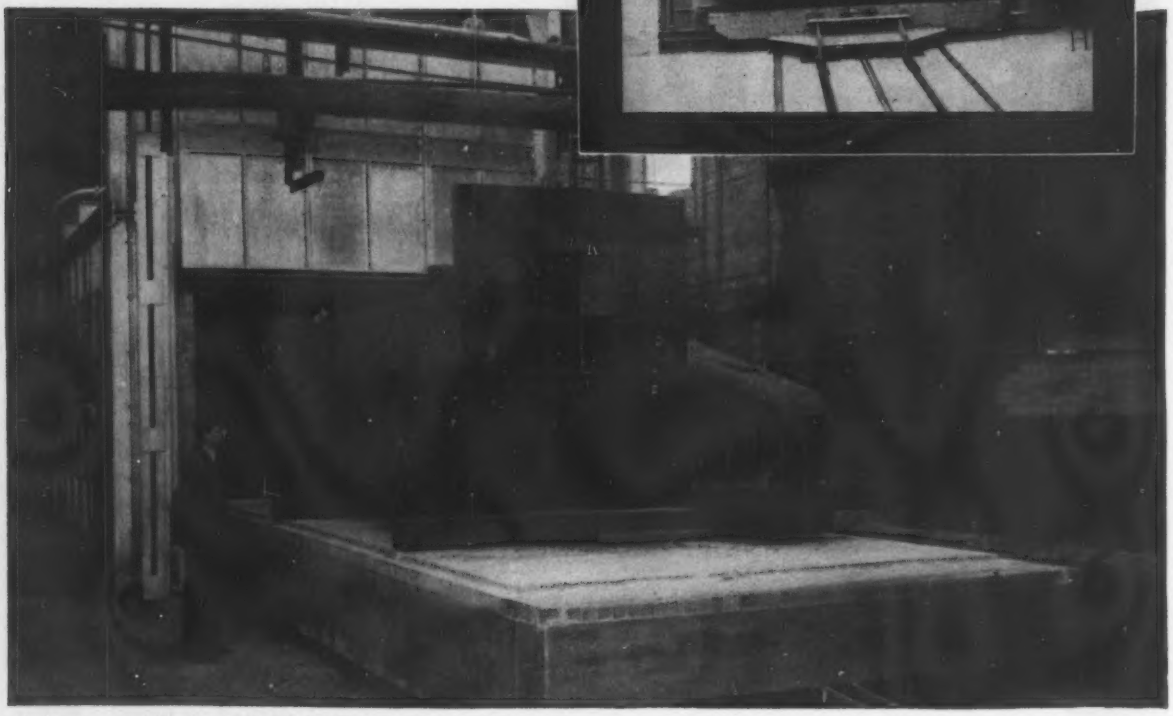
clean producer gas or oil
and with full instrumentation
a minimum temperature variation
is possible throughout the chamber.





By kind permission of Steel, Peech & Tozer.

WINCOTT FURNACES

G.P. WINCOTT LIMITED SHEFFIELD, ENGLAND

Telegrams: WINCOTT, SHEFFIELD. *Telephone: 20211/2*

SBW19.

Fifteenth century carving in St. Leonard's Church, Ribbesford, of a pig playing the bagpipes, with a sow and litter, and two pigs reaching for acorns. Photograph by Ruth Meyler & F. C. Sillar

50 MILLION PIGS GO TO MARKET!

In the early days of the industrial revolution manufacturers frequently looked for familiar and easily recognisable descriptions of their products. To the countryman transplanted into industrial surroundings nothing was more familiar than a pig; a fact which is emphasised by carvings in scores of old churches depicting pigs suckling their litter, rooting for acorns and playing the bagpipes. (Apparently this last pastime was forsworn by pigs many years ago because of unpleasant associations between bagpipes and pigs bladders.) Consequently, when iron from Blast Furnaces was directed into long troughs and from there into short and narrow troughs placed at right angles, a resemblance to sows suckling their appendaged litter led to the description of 'pig iron'.

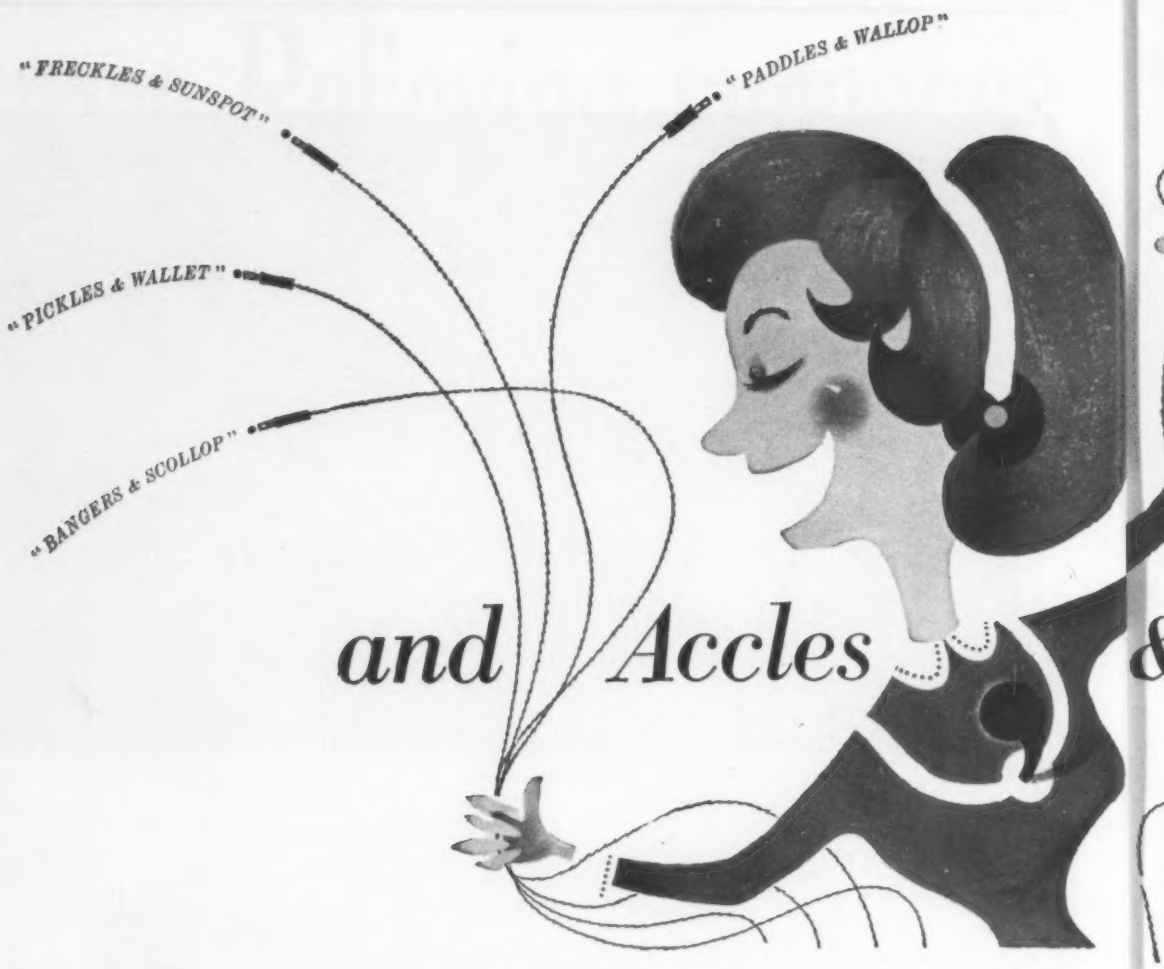
This series of advertisements illustrates some of the 'ecclesiastical' pigs and emphasises the 50,000,000 'special' pigs which Warner and Company have supplied to Iron Foundries producing High Duty Castings.

WARNER WARNER WARNER

"Pioneers of Refined Pigiron"

KA

WARNER & CO. LTD., MIDDLESBROUGH



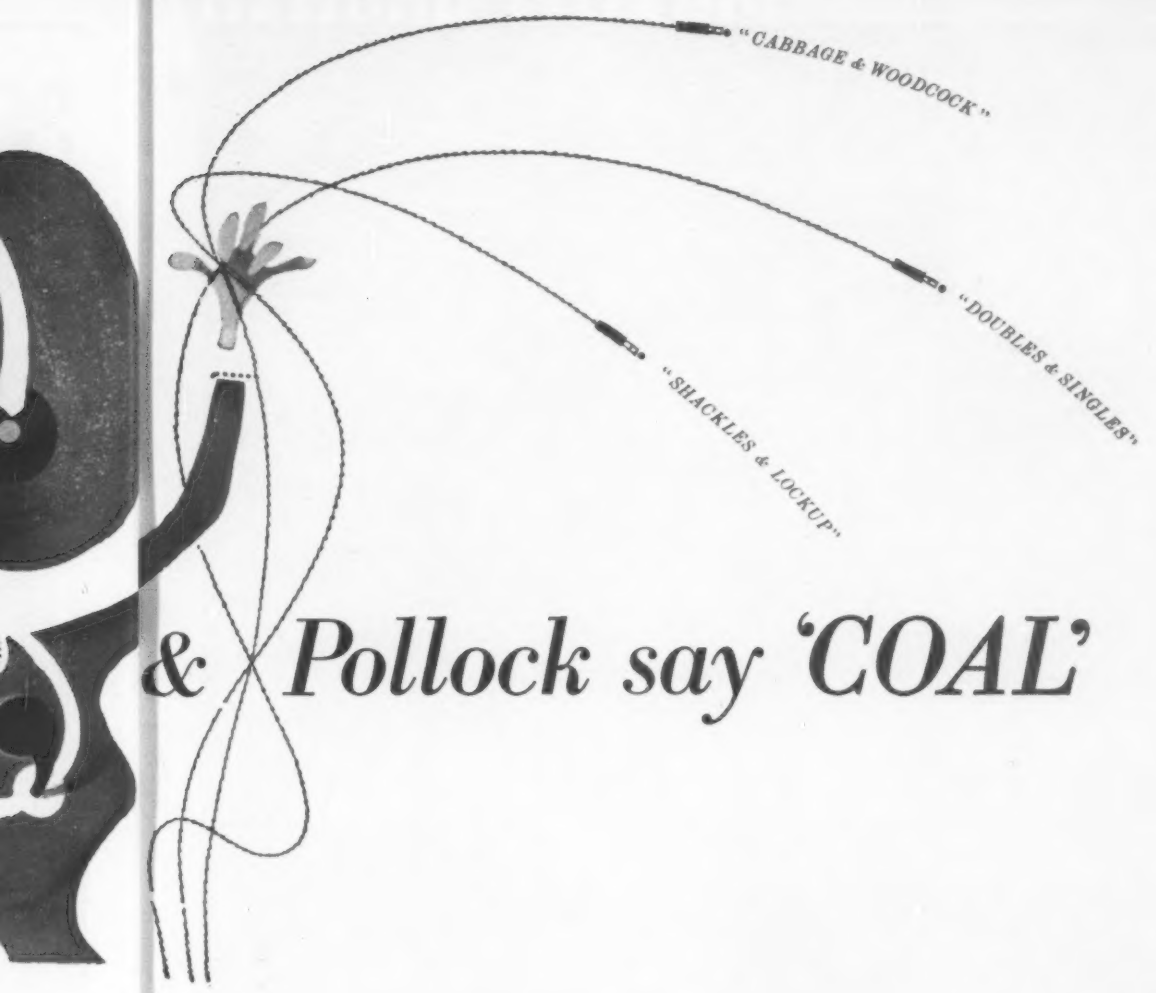
TO CHANGE a lump of stainless steel into a tiny tube ·011/·0115" o/d x ·005/·007" i/d, used for the manufacture of automatic knitting needles in the textile industry, is only one of the many miracles that Accles & Pollock create for science and industry at their works at Oldbury, Birmingham.

Behind this brilliant engineering know-how that will design and produce tubes of any size, any complexity, is the direction and impetus of a dynamic management that secures long-term advantages as well as immediate gain when making decisions. That's why Accles and Pollock choose *coal* to keep their boilerhouse at its efficiency peak. Their experience has proved that coal, mechanically stoked, *gives the maximum heat for the lowest cost:* and they know that there is no shortage of coal—the home produced fuel.

When the question of fuel for your factory is on the agenda, remember Accles & Pollock. Their choice is coal for a progressive and prosperous industry. Even if you get the name wrong, you get the decision right when you follow their example.

PROGRESSIVE INDUSTRY IS GOING FORWARD

ISSUED BY THE NATIONAL COAL BOARD



& Pollock say 'COAL'

Mr. W. E. Powell, fuel engineer, comments: "Our boilers were designed, primarily, for burning the slack grading of solid fuel. Following experiments into ultimate economies, however, it was decided to change to the better fuel of the 'bean' grading. Under test, it was found that solid fuel gave us excellent combustion conditions, at a challenging price per thousand pounds of steam. By making use of modern mechanical means of firing we are able to maintain strict control of operation practice.

The boilers are of the non-flue type, and when fitted with grit arresters they satisfy all local and national regulations governing grit and smoke densities.

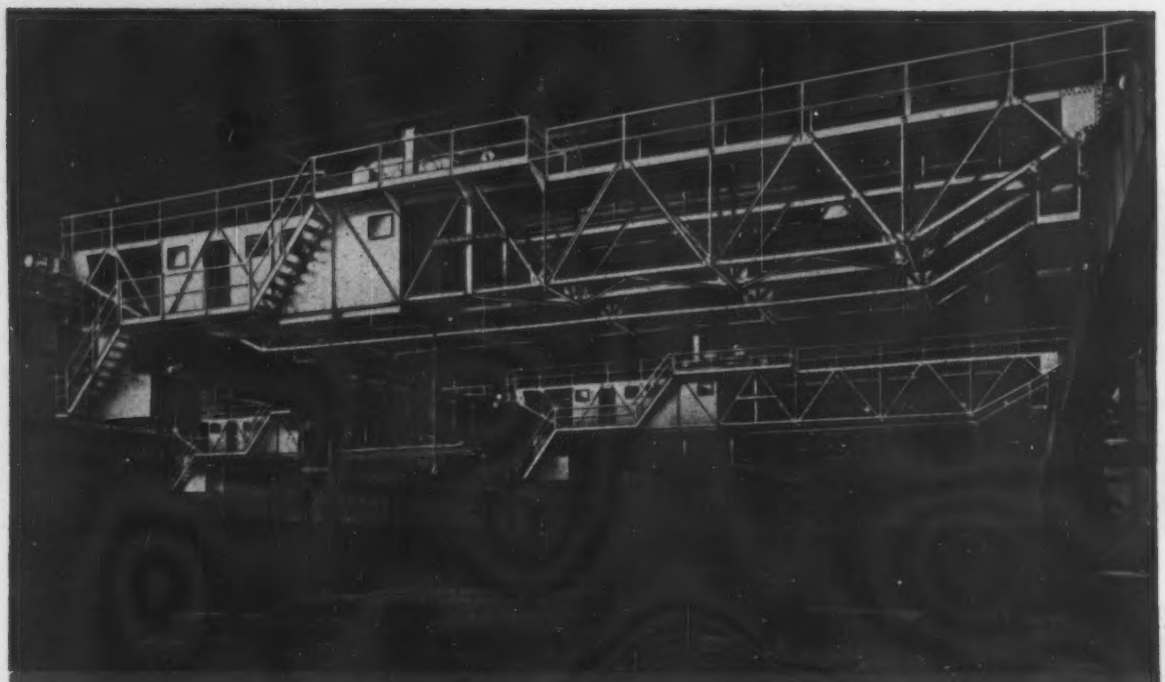
Most fuels can be controlled to give economical generation on the level obtained by solid fuel, but the use of coal does not entail the provision of ancillary equipment so necessary to the use of other heating mediums.

The present boilers have been in existence some ten to twelve years, and during that period we have experimented with all available means towards obtaining the best from our equipment. All our tests bring us back to the use of the 'bean' size coal. Given this heating medium, the operators have no difficulty in maintaining the efficiency level nominated by us. That is why we shall continue to use coal at Accles and Pollock."

And here are some key facts and figures about the Accles & Pollock boilerhouse at Oldbury

Number of boilers	5 water tube
Method of firing	Chain grate stoker
Steam pressure	120 lbs. per sq. inch
Steam temperature	340°F.
Continuous max. rating	72,000 lb. per hour
Annual fuel consumption	20,000 tons of coal

ON COAL



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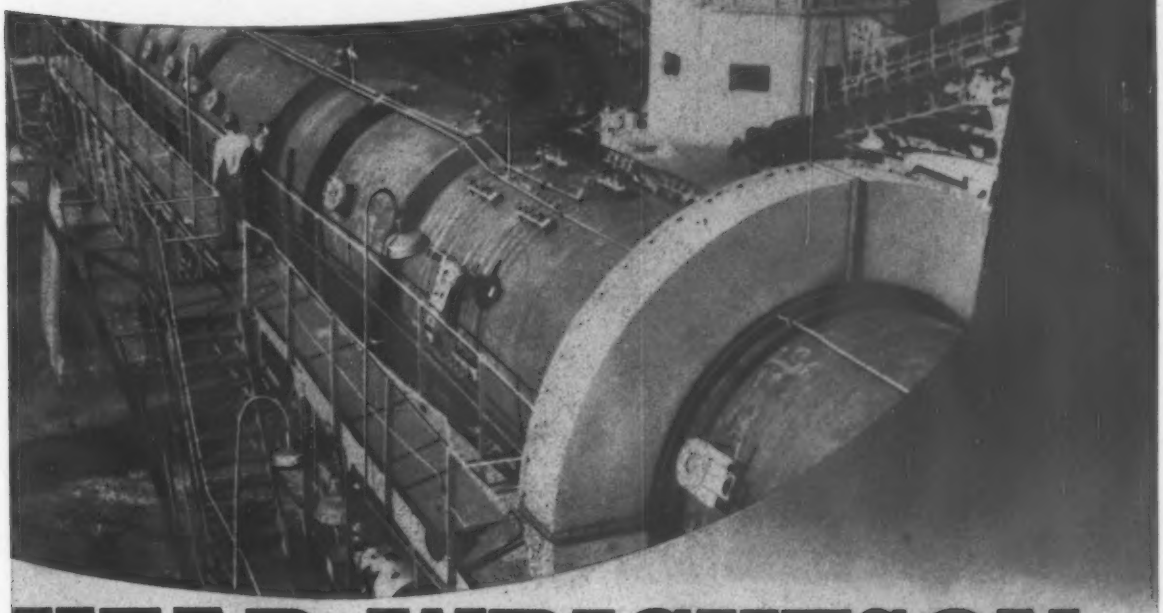
We invite you to write for full information on this new process. Our engineers are available to discuss the suitability of your own ore to this new method of direct reduction.

REMEMBER

- *The R-N process is not dependent upon the availability of coking coal.*
- *Capital and running costs are competitive with other direct reduction processes, but the R-N process has the technical advantage of subsequently removing the gangue.*
- *The R-N process can use ores and coal that today are not suitable for blast furnace plant.*
- *The R-N product is an excellent feed material for electric arc and open hearth furnaces as well as a convenient cooling material in oxygen converters.*



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Pouring Hot Metal in a 200 Ton Open Hearth Furnace, Abbey Works, The Steel Co. of Wales, by courtesy of whom this photograph is reproduced

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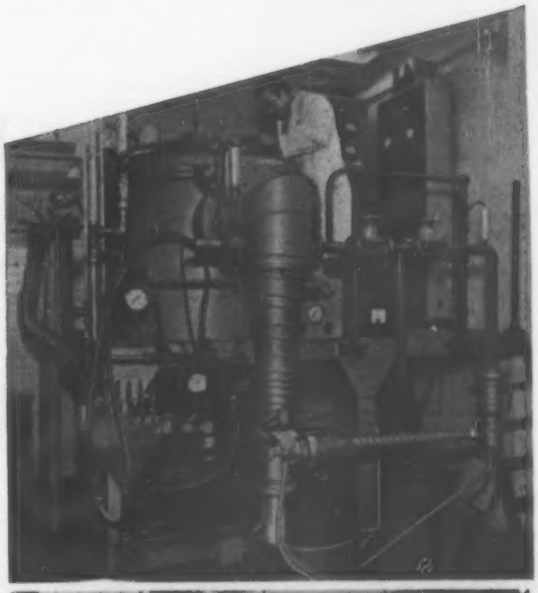
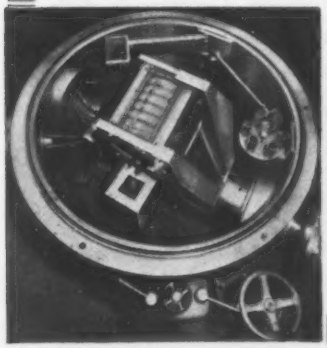


Top right: Edwards 56 lb furnace in use melting beryllium. (Courtesy of U.K.A.E.A.)

Bottom right: Edwards 56 lb furnace in use producing special steels (Courtesy of G. L. Willan Ltd.)



INDUCTION COIL ASSEMBLY

In every case the coils are fully insulated for working up to a maximum voltage of 440 volts and the special insulating technique used enables the furnace to operate at voltages at which a corona discharge would occur if a non-insulated coil were used. The assembly is designed for lip pouring and is tilted by a co-axial power seal about an axis through the lip of the crucible. A suitable generator or valve oscillator set can be supplied but where existing electrics are to be used a high frequency supply is required at 400 V, of 2 to 10 kc/s (optimum 5 kc/s), 30 kW for the 28 lb furnace or 50 kW for the 56 lb and 100 lb furnaces.

- Choice between 28 lb, 56 lb, 100 lb interchangeable coil assemblies.
- Rapid and accurately controlled melting by high frequency induction heating.
- Specially developed 'Speedivac' pumping system gives very high speeds in pressure region of major gas evolution from melt. This system has high tolerance to contaminants.
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- Earth leakage relay device cuts out power supply in the event of crucible lining failure.
- Immersion pyrometers for temperature measurement up to 1800°C.

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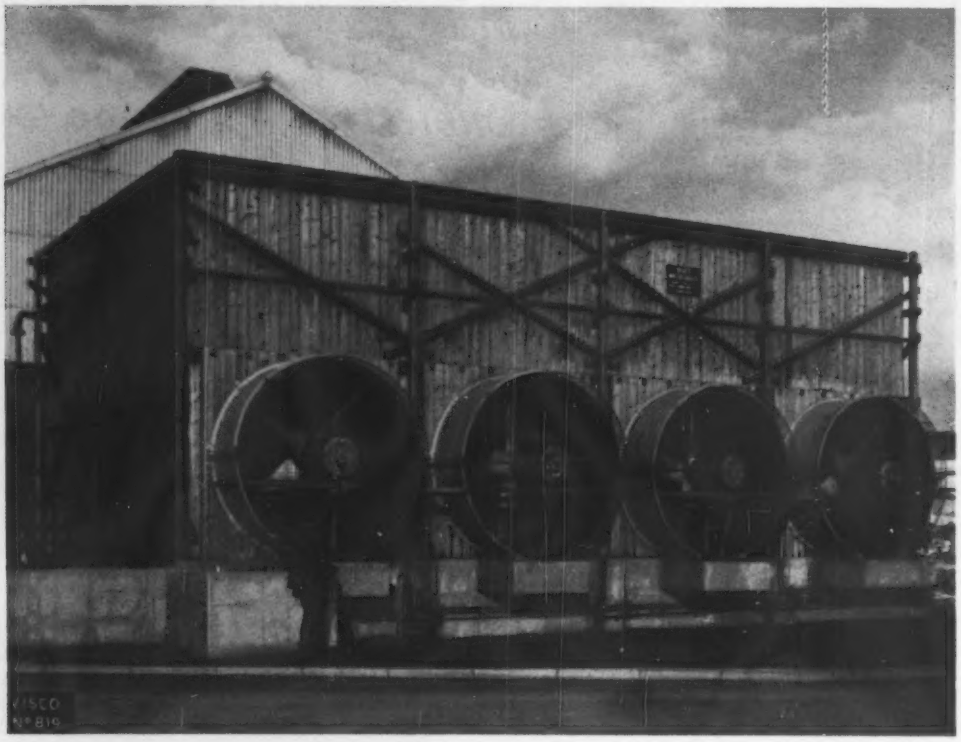

Photograph by courtesy of Alcan Industries Ltd.

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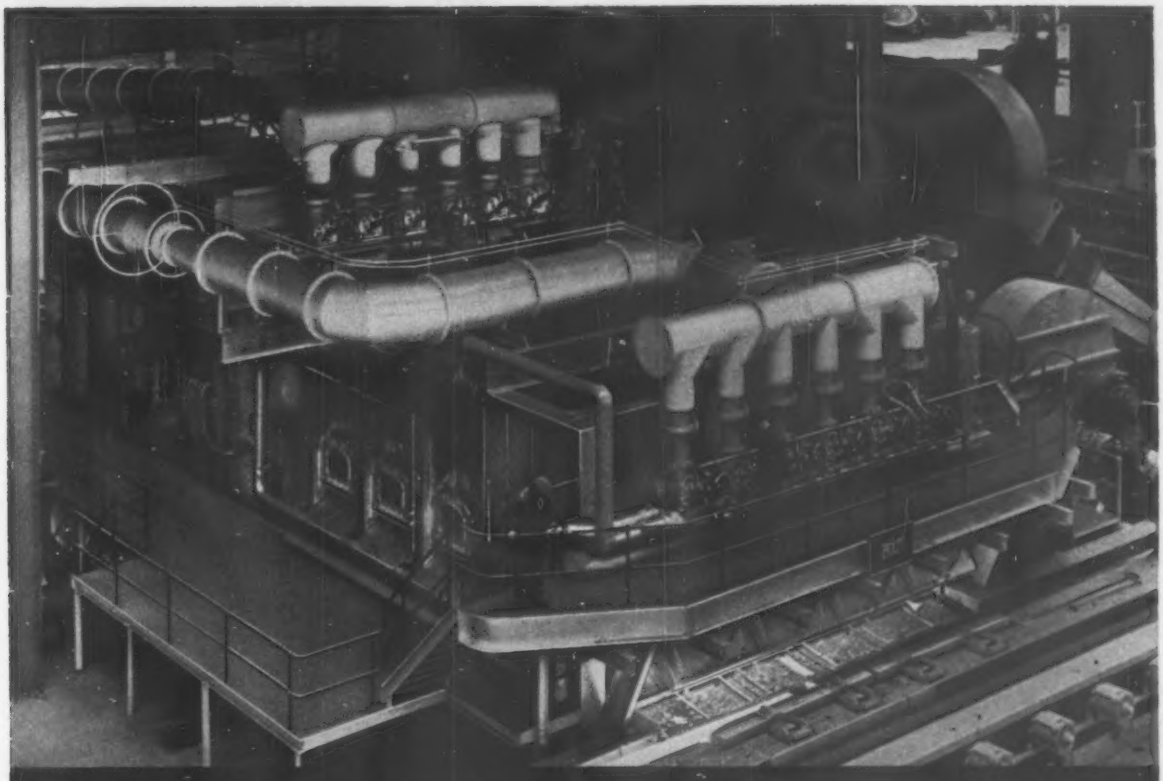

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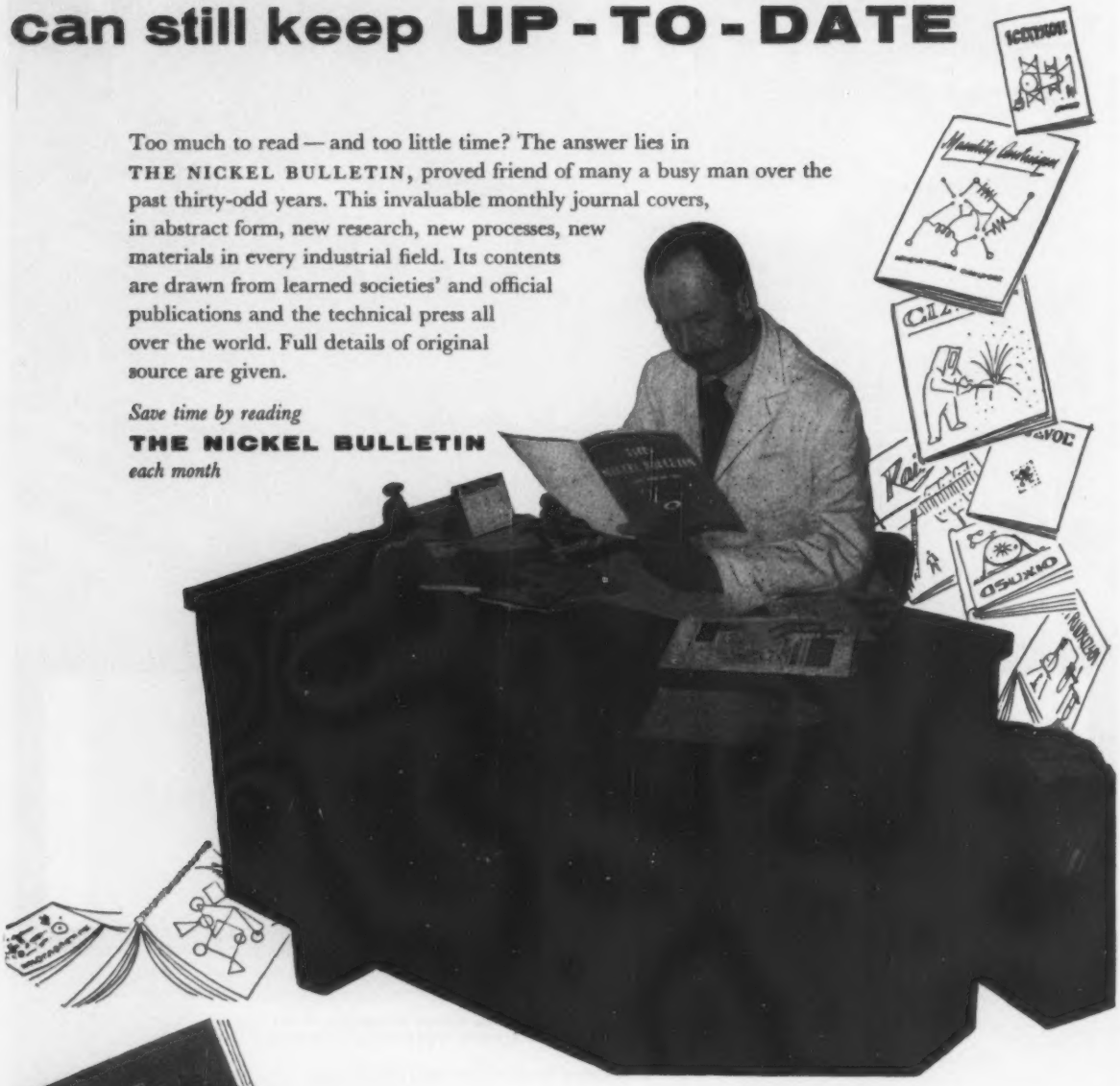

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The steam conditions of 3300 p.s.i. and 1060°F are the highest yet commercially used in Great Britain. The associated back-pressure turbo-alternator gives an output of 9500 KW (approximately 30% increased on the installed capacity of the existing generation plant). Process steam is exhausted at 650 p.s.i.g. and reheated to 820°F to serve the new turbo-blowers and the existing system.

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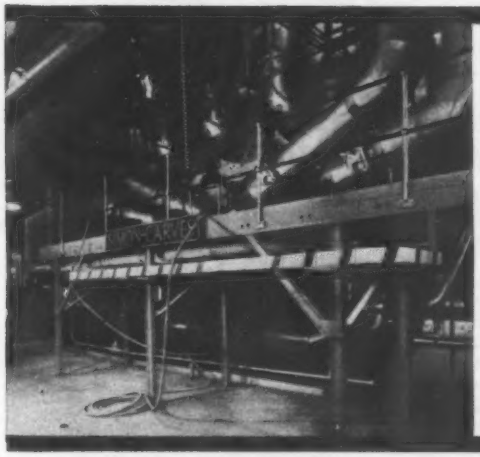

left. The operating front of the boiler is housed in the turbine building. Fuel can be blast furnace gas or fuel oil or a mixture of both.

right. The central control panel. From here, both the boiler and the high pressure turbines are controlled.

O T FORCED-CIRCULATION BOILERS BY

Simon-Carves Ltd

MEMBER COMPANY SIMON ENGINEERING LTD

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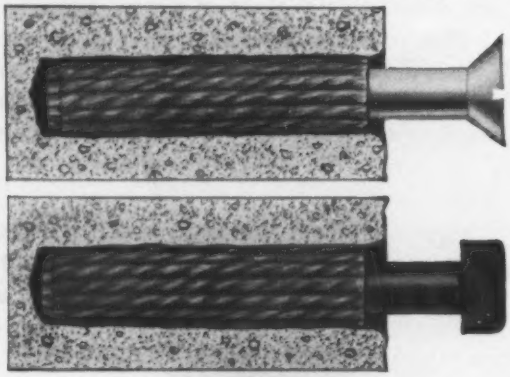

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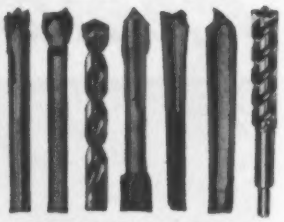

R.P.2 *Two-speed* ELECTRIC DRILL

Keyless Chuck

At the touch of a button you can change the speed of this drill from 1200 r.p.m. to 420 r.p.m. which is the ideal speed for Durium Masonry Drills. Chuck capacity is 5/16″. Finger tightening holds the smallest drill in rigid grip which increases with the load yet can be easily released.

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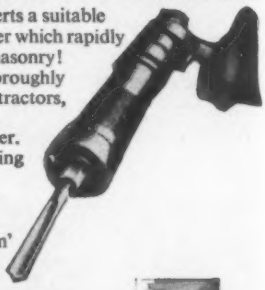

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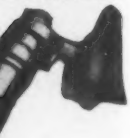

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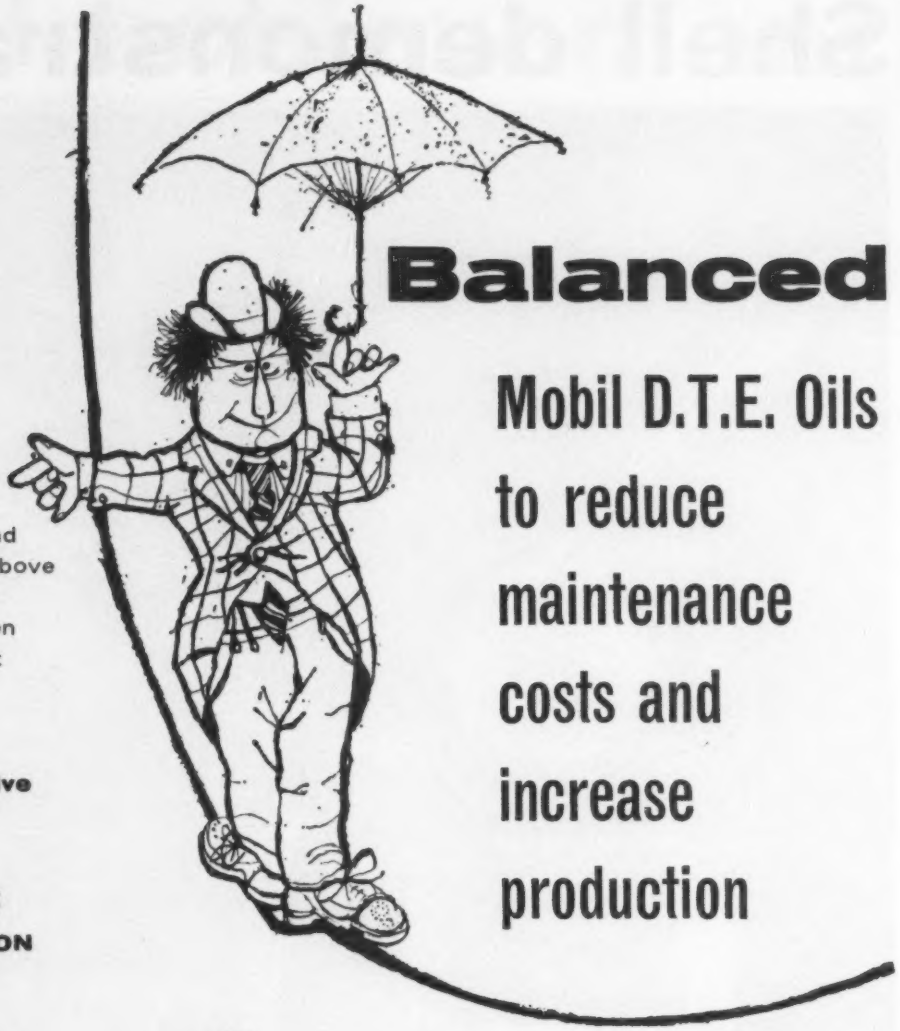

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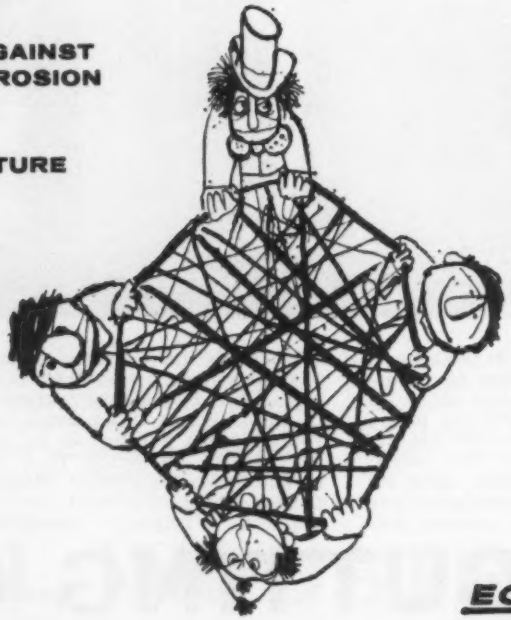

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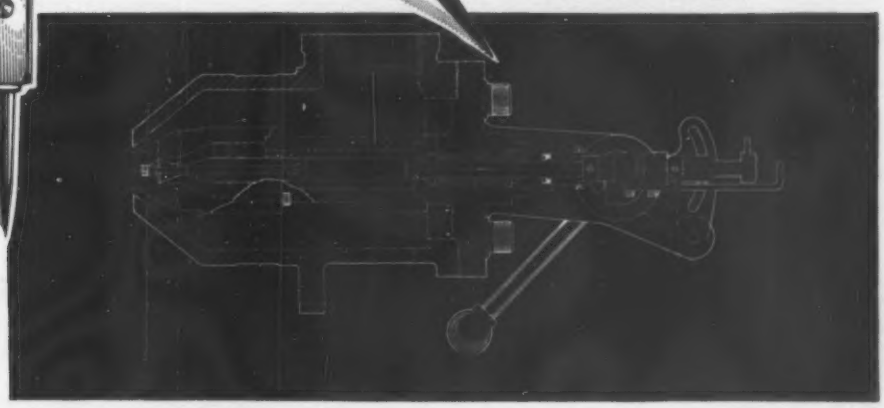

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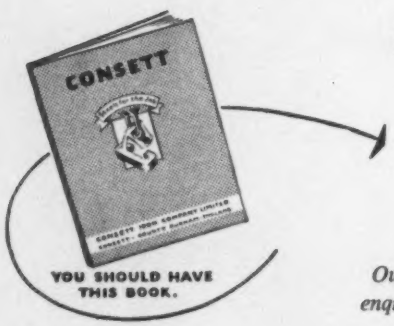

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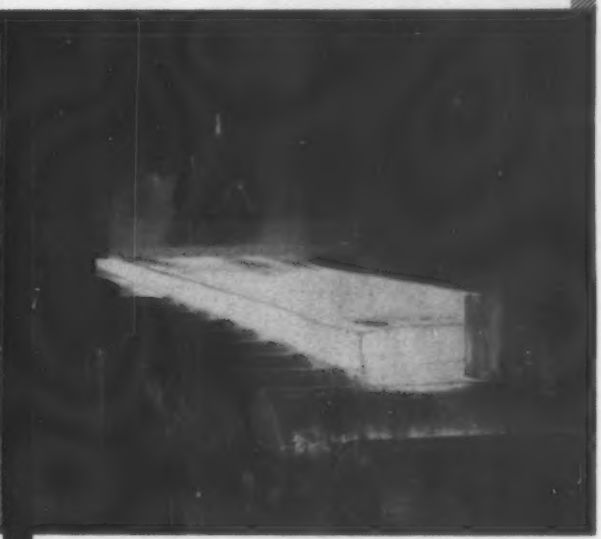
"Stellite" faced roller twist guides on this Continuous Mill handle approx. 10,000 tons of ⅜" bar before resurfacing is necessary.

Illustration by courtesy of Park Gate Iron and Steel Company Ltd., Rotherham.



"Stellite" faced hot shear blades are standard equipment in most plants for cutting blooms and smaller sections.

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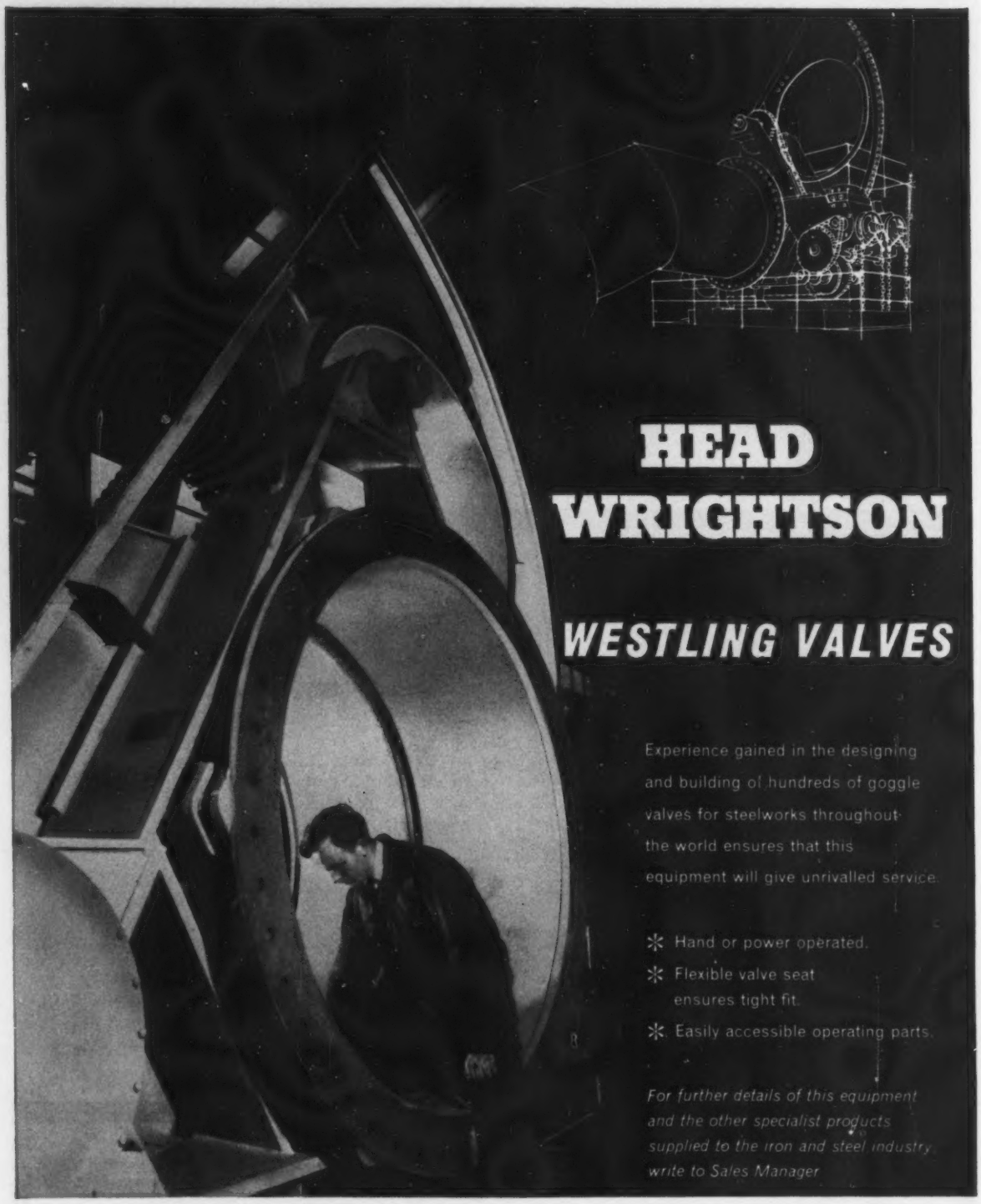
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Experience gained in the designing and building of hundreds of goggle valves for steelworks throughout the world ensures that this equipment will give unrivalled service.
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When flue gases escape into the air they're gone for good, and with them goes the chance of a big fuel saving. With a Senior Economiser you can use these gases to pre-heat the feed water, saving 10-20% of your fuel, increasing the efficiency of your boiler plant, cutting the cost of steam.

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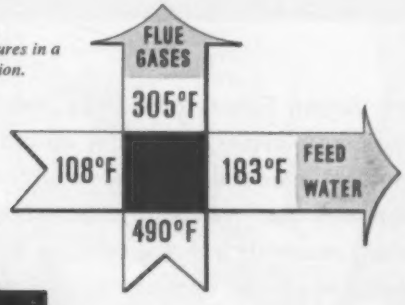
Why not write for further details?

Diagram shows temperature figures in a typical installation.



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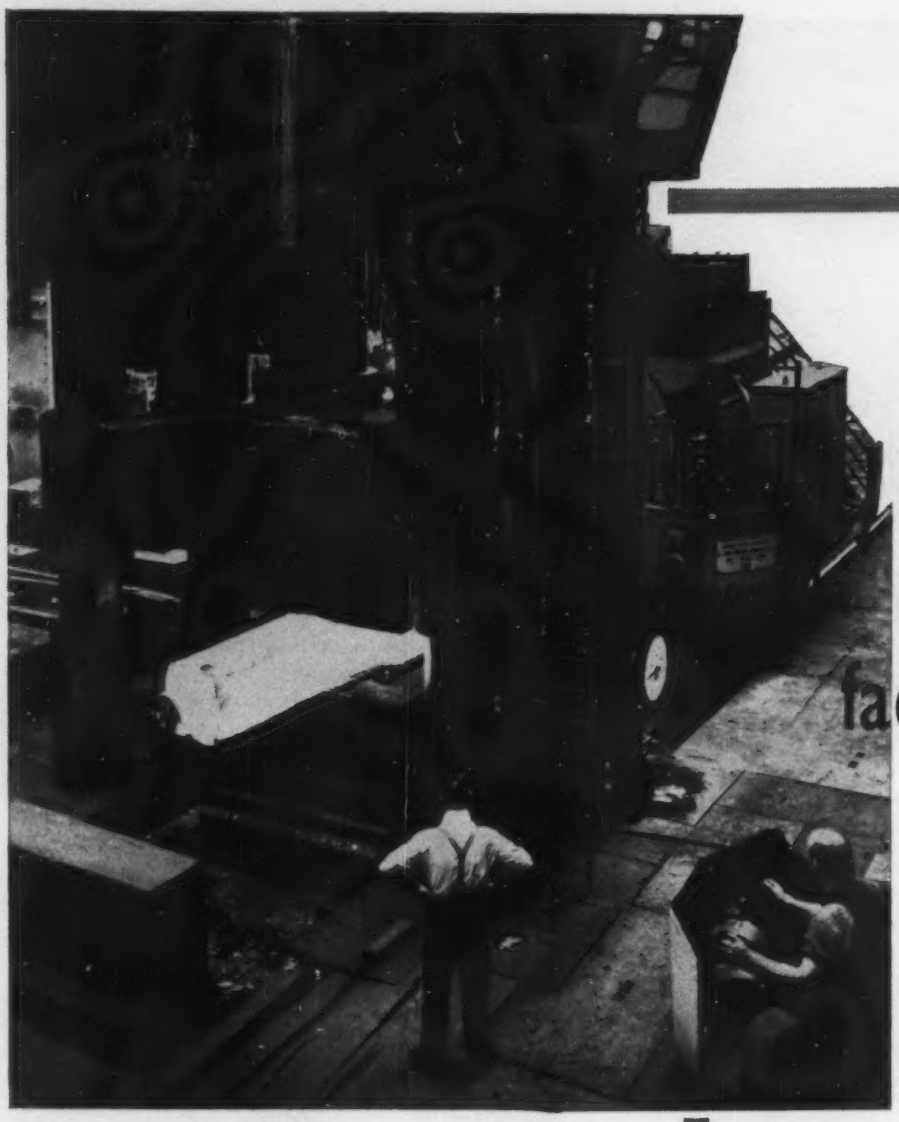

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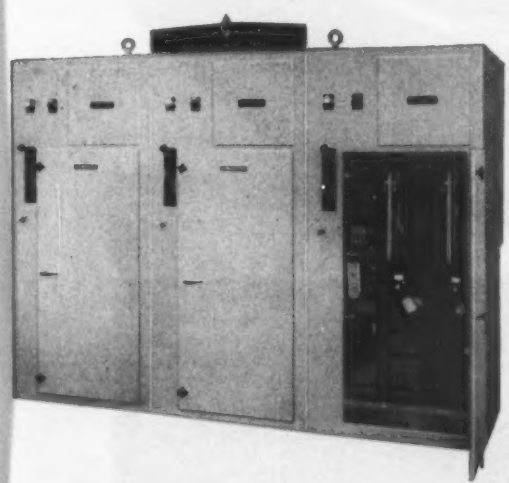

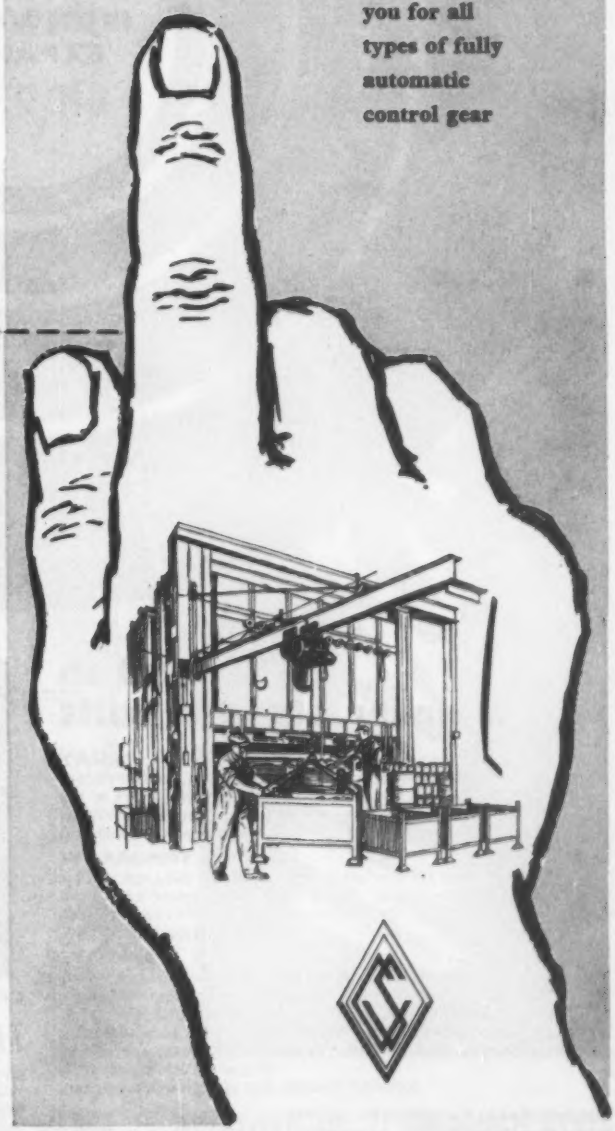

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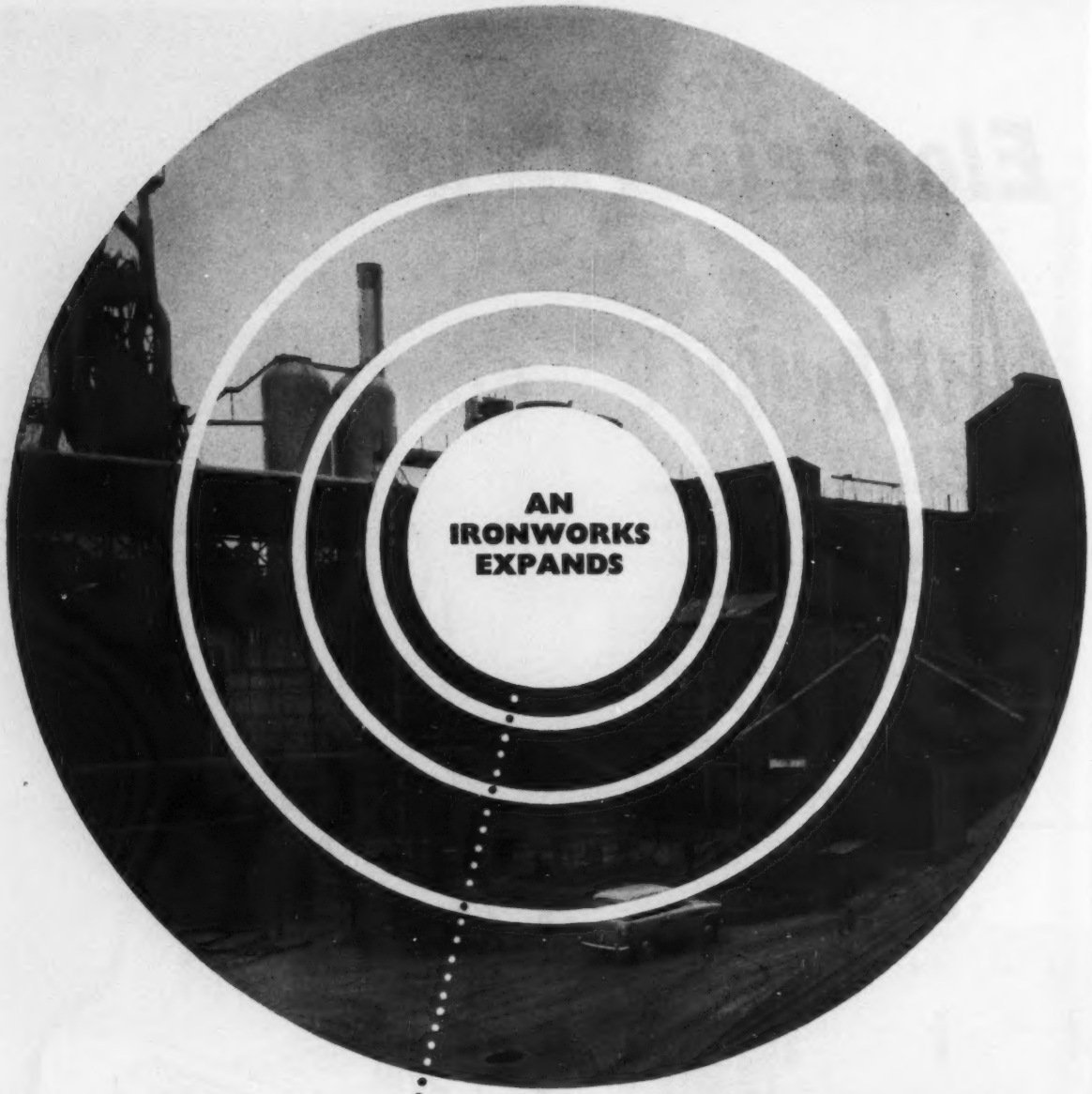

and so a sinter plant is built

TODAY

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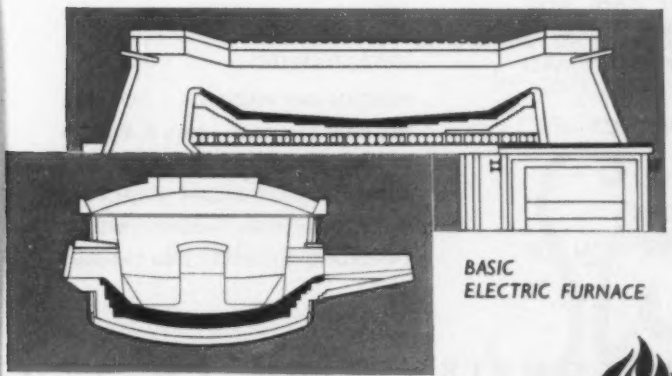

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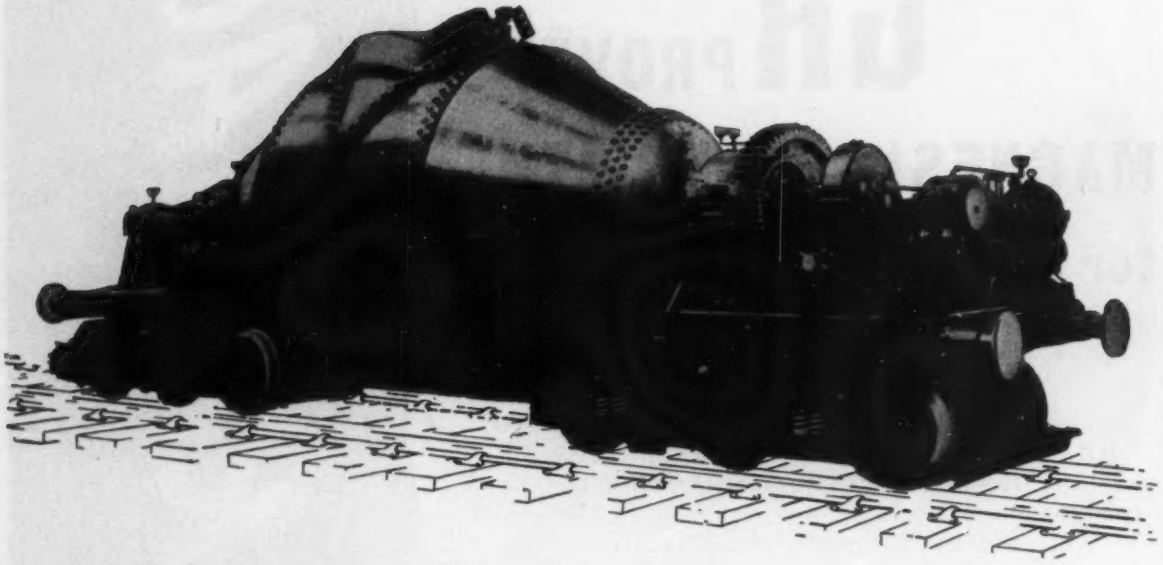

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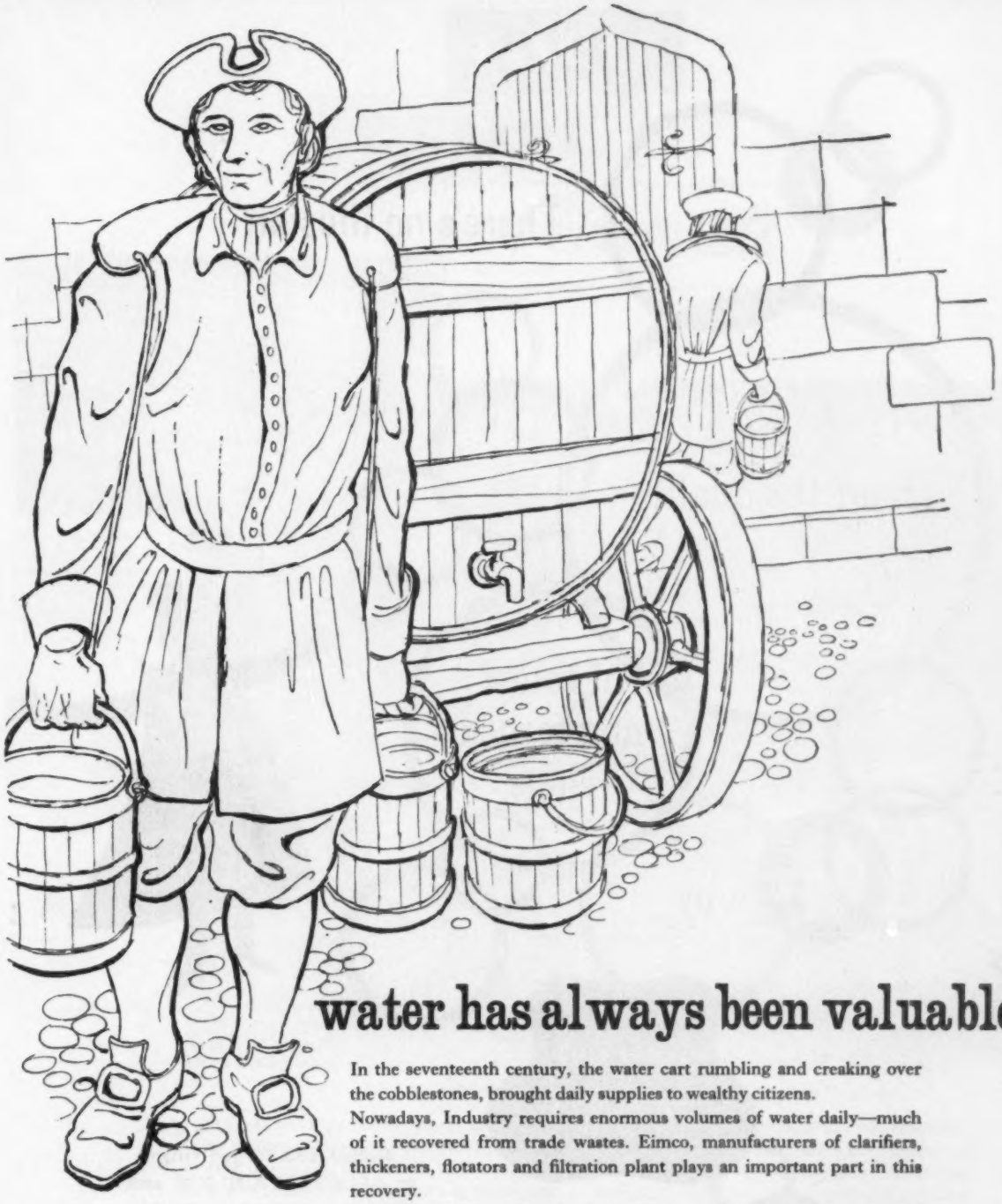

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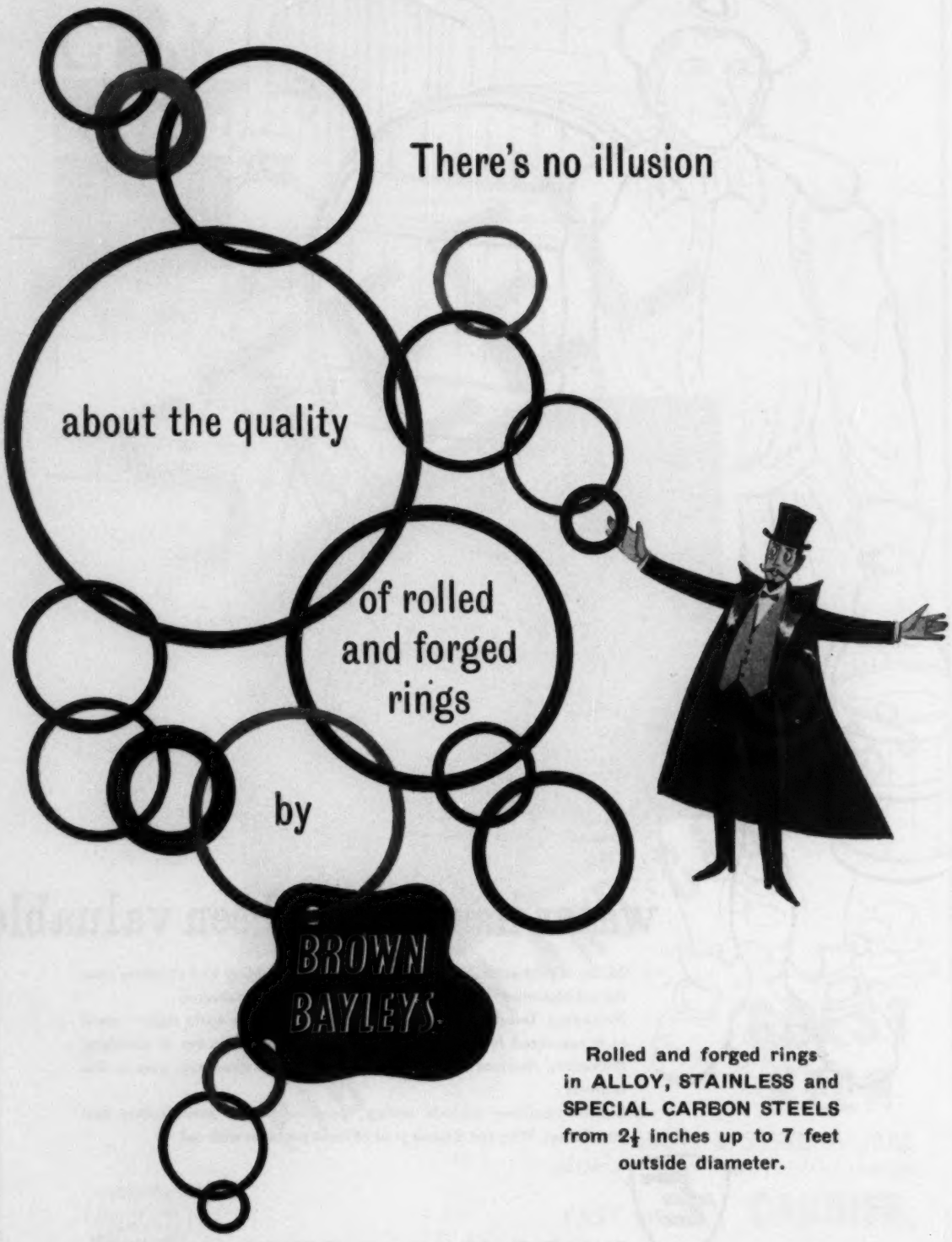

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from 2¼ inches up to 7 feet
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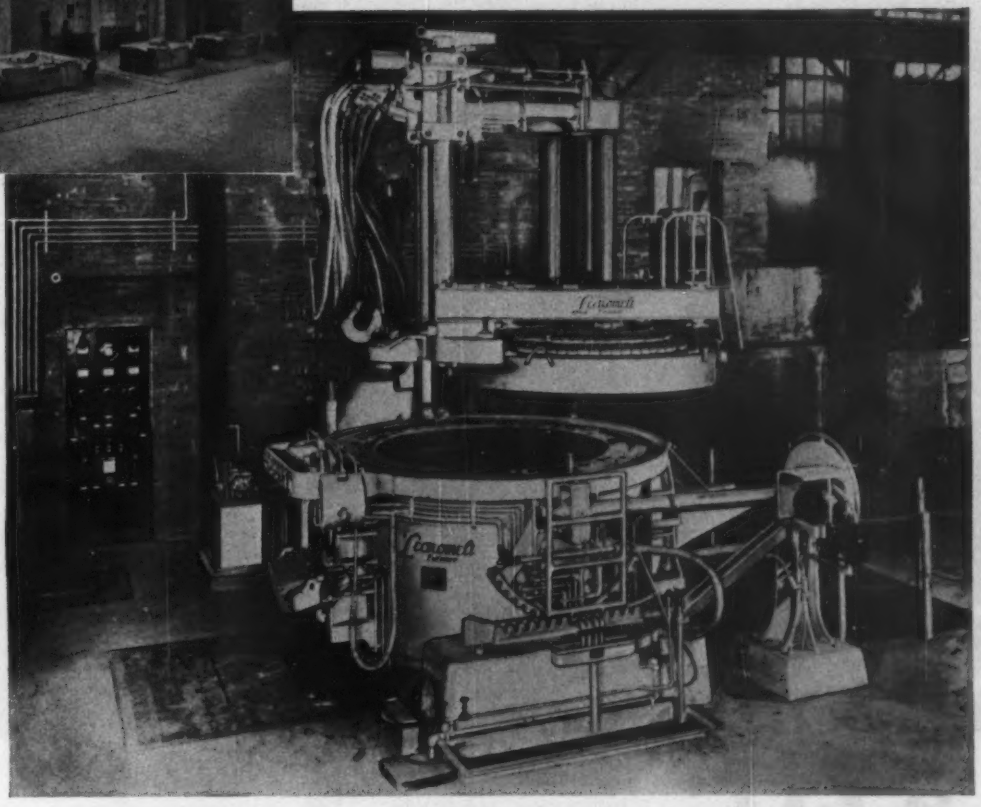
DEMAG Lectromelt

Demag high-frequency induction furnace installation at a steel making plant, incorporating two 1 ton capacity furnaces, two 660 lb. capacity furnaces, and one 110 lb. capacity furnace.



A 3 ton capacity Lectromelt arc furnace of 9' 0" diameter shown with roof swung ready for charging.

High Speed and High Output are the key features in the medium and smaller range of furnaces offered by G.W.B. Furnaces Ltd. Many years are behind both the Coreless and Arc Furnaces of Demag and Lectromelt designs.

Daily, electric furnaces are finding wider and wider applications, and the coreless induction (crucible) type is no exception as it is an ideal medium for melting steel and iron, and all other metals. It is particularly advantageous in steel works where a charge of scrap of known analysis is melted and is an installation that pays for itself in a very short time.

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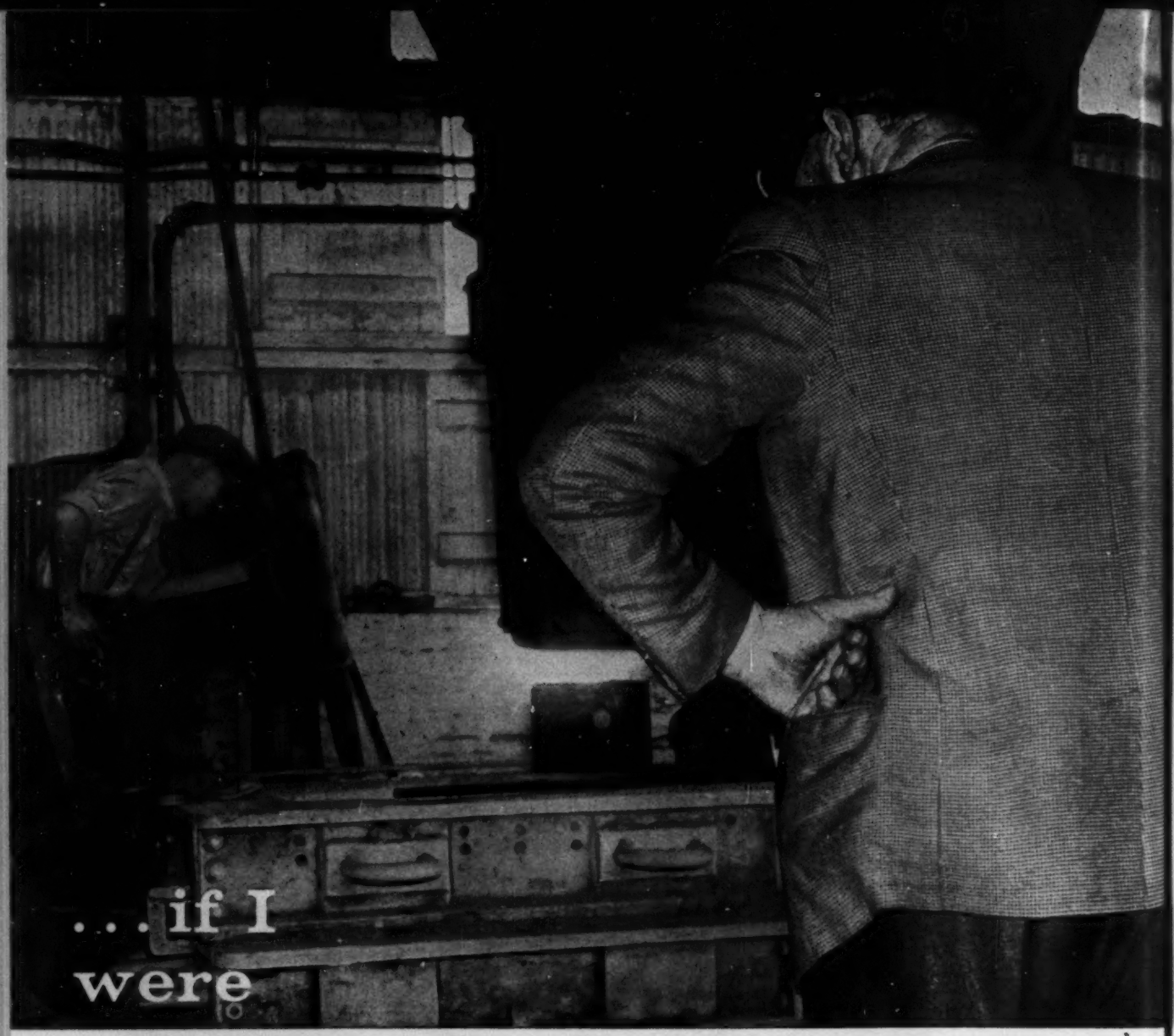

a Q.C.

". . .'Members of the Jury' I'd begin—and I reckon that would be my lot.

"You want a cool, calculating brain to tackle a job like that. Every step planned in advance—on your toes every minute of the day and heaven help the client if you make a mistake.

"A bit like casting a roll when you come to think of it—except for the talking. Always one move in front of the metal, every detail worked out to a hair-breadth and all the time Charlie, the crane driver, is sitting in his box like a blooming judge.

"As for the Jury? Well, I reckon all of us at AW fill that bill, but speeches won't sway us—it's the **result** that counts here."

CLOSELOY ROLLS – perfection in Roll technique

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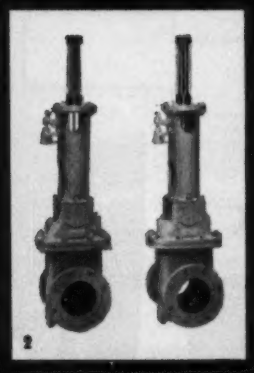
POWER OPERATED HOLMES-WESTERN '55' GAS VALVES

Holmes-Western Valves can be arranged for semi or fully automatic operation, and can, where required, be remote controlled. All electrically operated valves are available in flame-proof, weather-proof and dust-proof designs.



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1 **Electric Motor Operated**
A group of valves fitted with Rotork Actuators. Valves of this type have provision for manual operation in the event of a power failure.

2 **Hydraulic Cylinder Operated**
Two valves fitted with hydraulic cylinders. Pneumatic cylinder operation is also available.

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A valve fitted with a dust-proof pull-type solenoid. This valve is designed to close automatically in the event of a power failure.

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A valve arranged for air drill operation. This semi-automatic method of operation is particularly suitable where full mechanisation is not justified.

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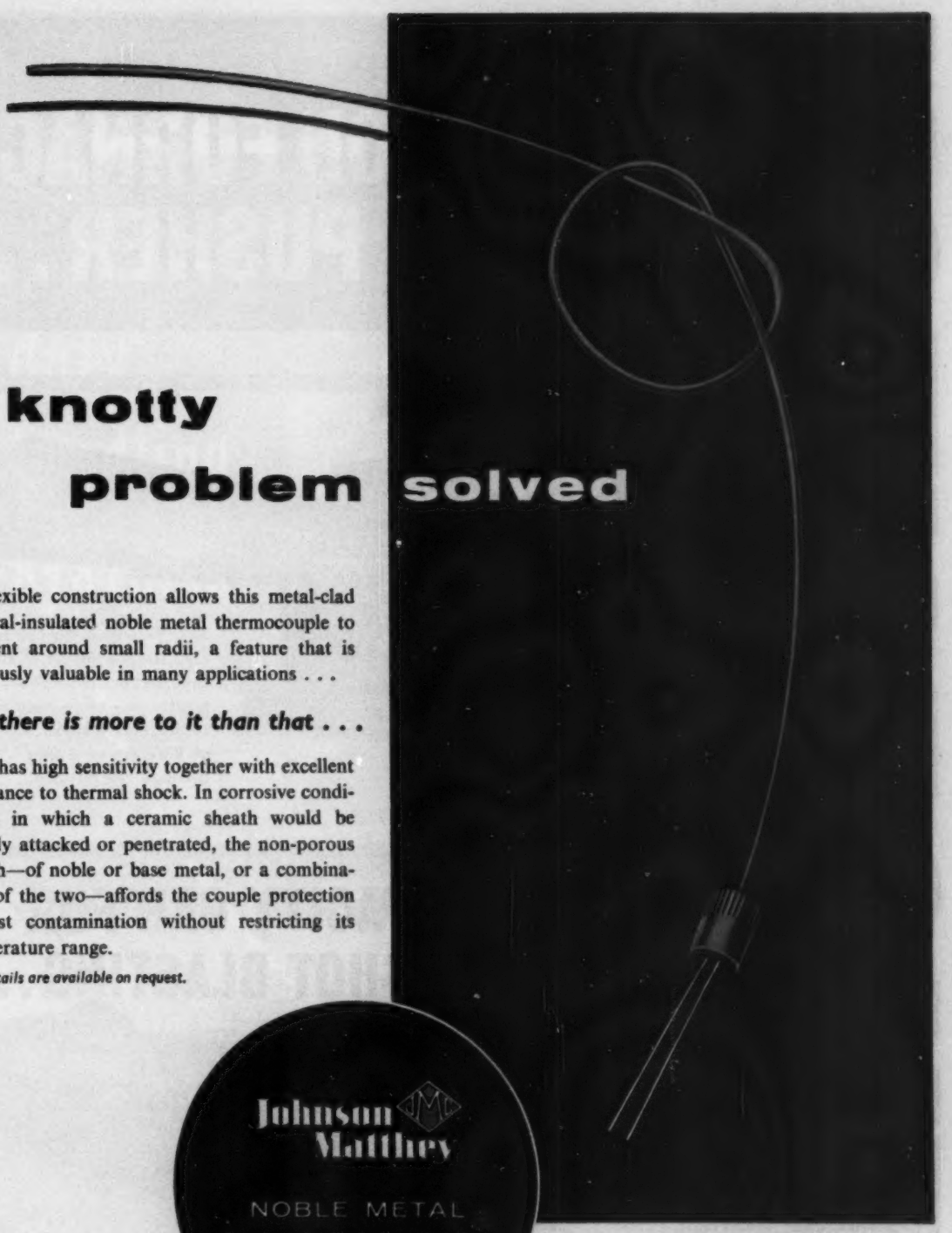

a knotty problem solved

Its flexible construction allows this metal-clad mineral-insulated noble metal thermocouple to be bent around small radii, a feature that is obviously valuable in many applications . . .

but there is more to it than that . . .

for it has high sensitivity together with excellent resistance to thermal shock. In corrosive conditions, in which a ceramic sheath would be rapidly attacked or penetrated, the non-porous sheath—of noble or base metal, or a combination of the two—affords the couple protection against contamination without restricting its temperature range.

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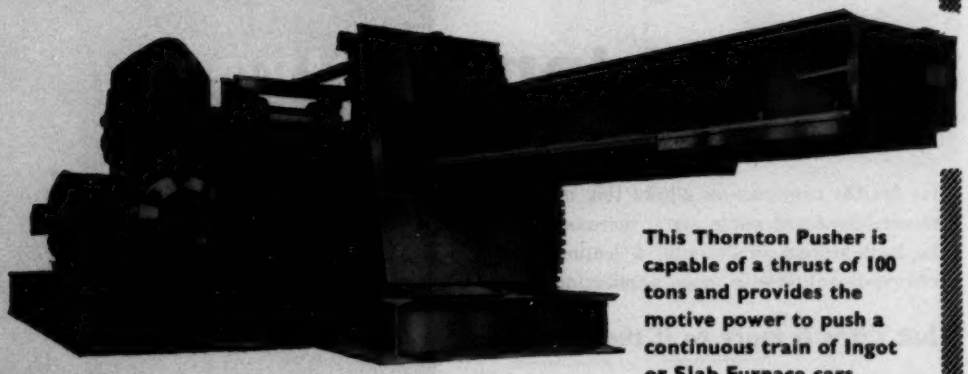

This Thornton Pusher is capable of a thrust of 100 tons and provides the motive power to push a continuous train of Ingot or Slab Furnace cars through the furnace.

60 TON CAPACITY CAR FOR SHOT BLASTING...

We designed this car with all-round rubber screening to provide added protection when bearing heavy castings for cleaning in a shot-blast chamber.

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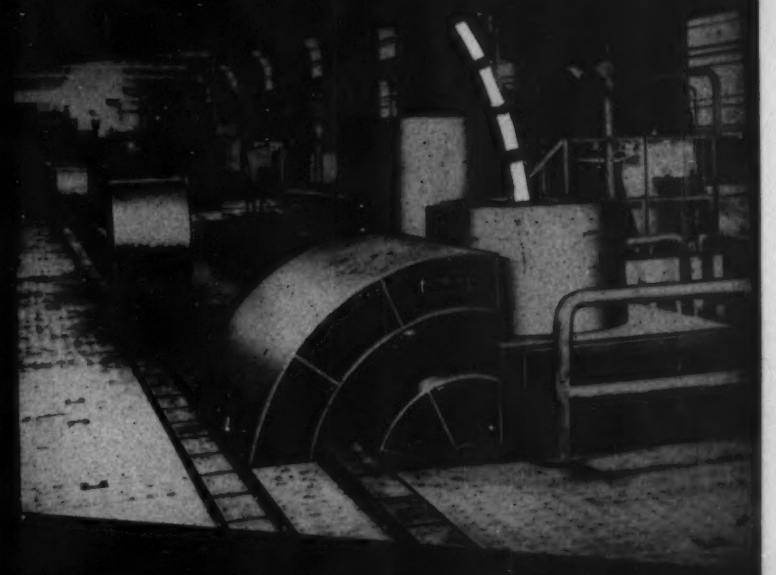
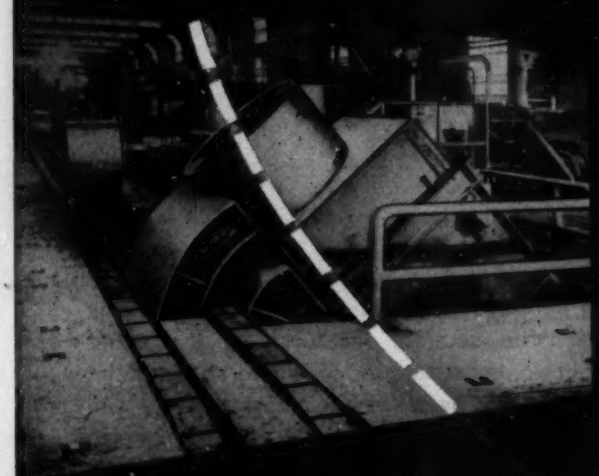
PANTIN

heavy–duty handling systems



Pantin design and manufacture heavy duty mechanical handling plant for the Iron and Steel Industry.

This 'Upender', for example, was made to simplify and expedite the handling of coiled steel. With the utmost ease it takes coils up to 15 tons (max. dimensions 6' diam. – 6' wide) and lays them on a Pantin Pallet Conveyor for movement to the next station.



Pantin Handling Equipment covers every requirement, including upending and downending, tilting, hoisting and conveying of coils and sheets.

We are always pleased to discuss, advise and co-operate on the design of handling systems and shall be glad to send you details of Pantin Conveyors and Handling Equipment. Please write for illustrated brochure.

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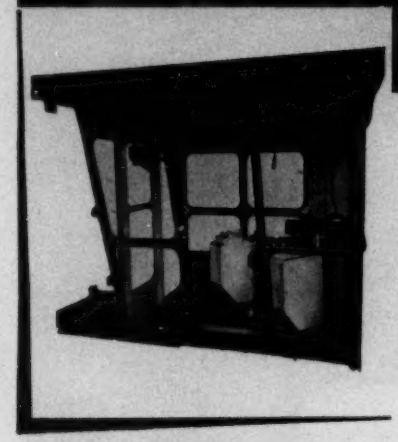

★ *a view of the cab showing the seat control unit.*

The Adamson 50/10 ton crane is the third of a series of new design supplied to Richard Thomas & Baldwins Limited, Ebbw Vale Section. Features of the crane include monolithic construction of the crab and the elimination of castings by mild steel fabrication of the hoist barrel and bottom block. The cab is of particular interest as it incorporates the most modern type of seat unit ensuring maximum vision and ease of control. Joseph Adamson electric overhead travelling cranes can be supplied to all specifications including cranes suited to the most exacting 24 hours-a-day process work.

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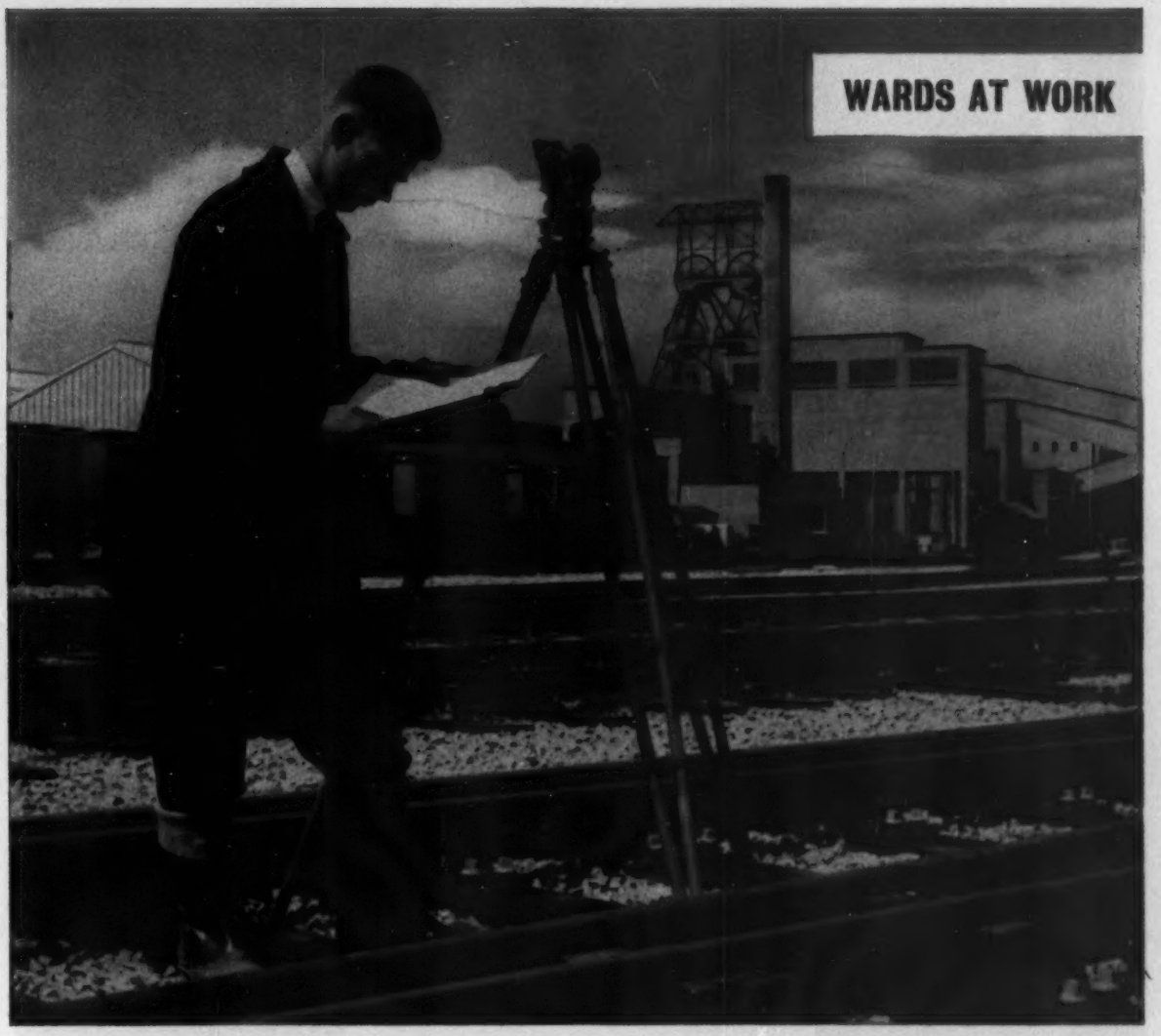

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He's a surveyor working on a Ward's siding contract. He belongs to one of the many Ward's teams of skilled engineers, foremen and workers who undertake the construction of industry's own railways. With their sixty years' experience in this field, Wards are in a unique position to advise on the practical and economical layout of tracks.

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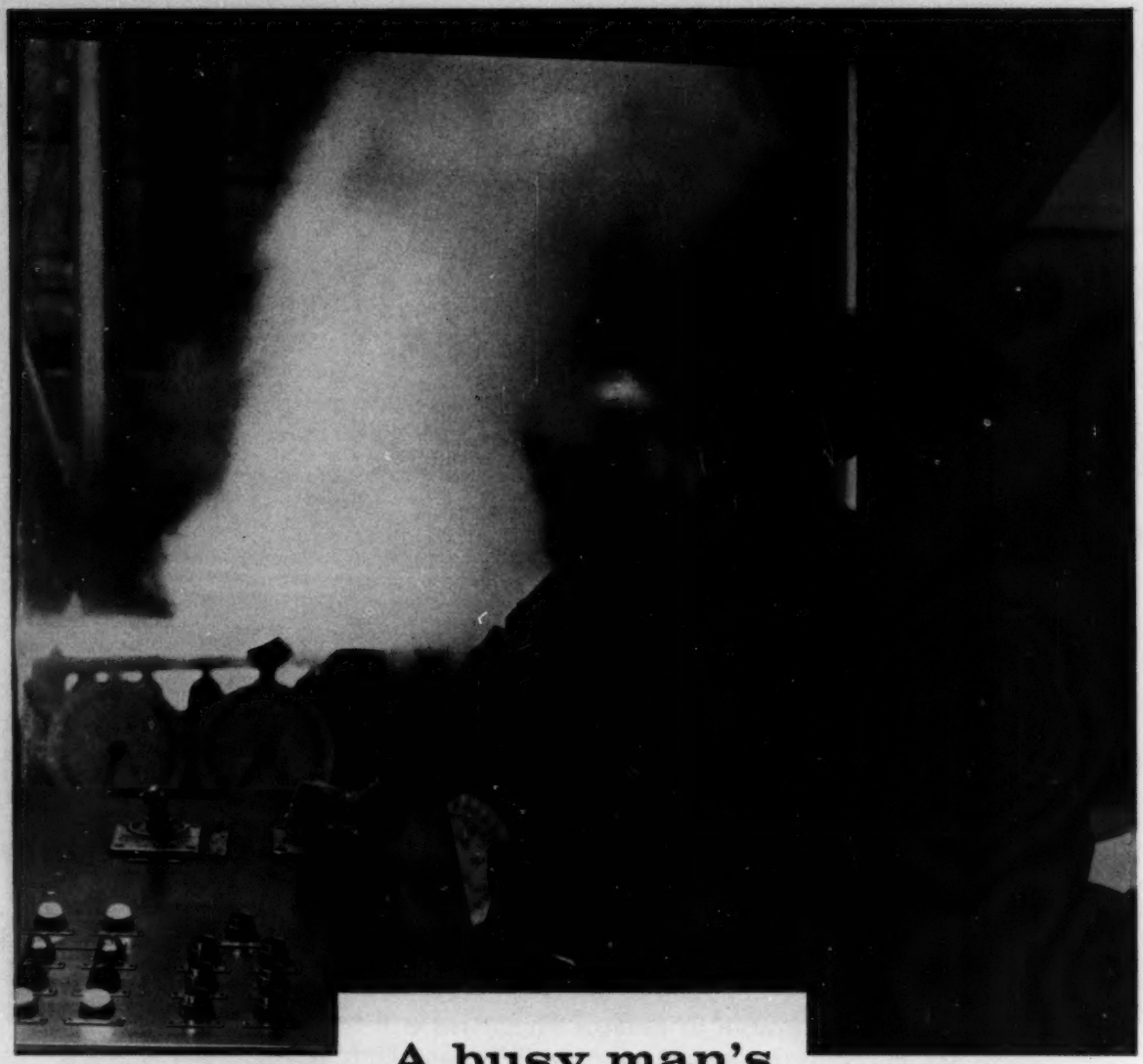

A busy man's guide to Britain's steel progress

WINSTON CHURCHILL kept his finger on the pulse of things by asking for important information "on one side of a sheet of paper".

The post-war achievements of the British steel industry would fill a book. Here, for the busy man whose eye we have this minute, is an account of what is happening now.

PRODUCTION The British steel industry produced over 24 million tons of steel in 1960 – compared with 20 million tons in 1959. Output is now about *double* the pre-war figure. Production of alloy steels – especially stainless steel – is expanding particularly rapidly.

PLANT Since the end of 1946, almost £900,000,000 has been spent on development. Continued modernisation and expansion – now costing some £130,000,000 a year – will provide steel capacity for over 34 million tons by 1965. Pig iron output per furnace and open hearth steel output per furnace are both more than double pre-war. With the need for ever-increasing efficiency and economy, ore beneficiation has made great strides and fuel consumption per ton of iron has been reduced by about 25 % since the war. Use of oxygen for steelmaking is rapidly increasing.

INDUSTRIAL RELATIONS The industry keeps its remarkably good record for settling industrial disputes without recourse to strike action. British steel workers are often sons and grandsons of steel workers, richly endowed with traditional skills. Making steel exactly to specification is more than a commercial requirement; it's a matter of pride.

PRICES British steel prices have been keenly competitive since the war with those of other major European producers and well below the American price level – and the quality of British steel is unsurpassed.

THE BRITISH IRON AND STEEL FEDERATION

METAL CASED BASIC BRICKS

now made by

Pickford Holland

Under sub-licence from General Refractories Ltd., covered by British Patent No. 546,220 for the basic process of metal-cased brick manufacture and other British Patent No.'s 600,630—749,491—778,047 and 778,048.

METALCLAD "EE" BRICKS

Divided internally by two plates placed lengthwise. This system reduces flaking and spalling to a minimum and can be applied to all Metalclad shapes and sizes.

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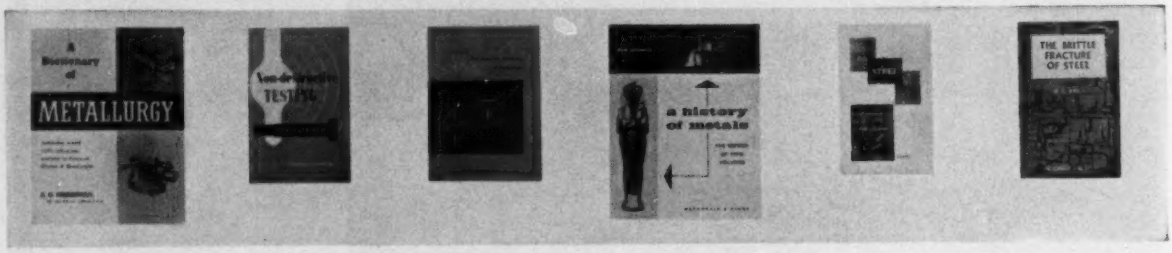

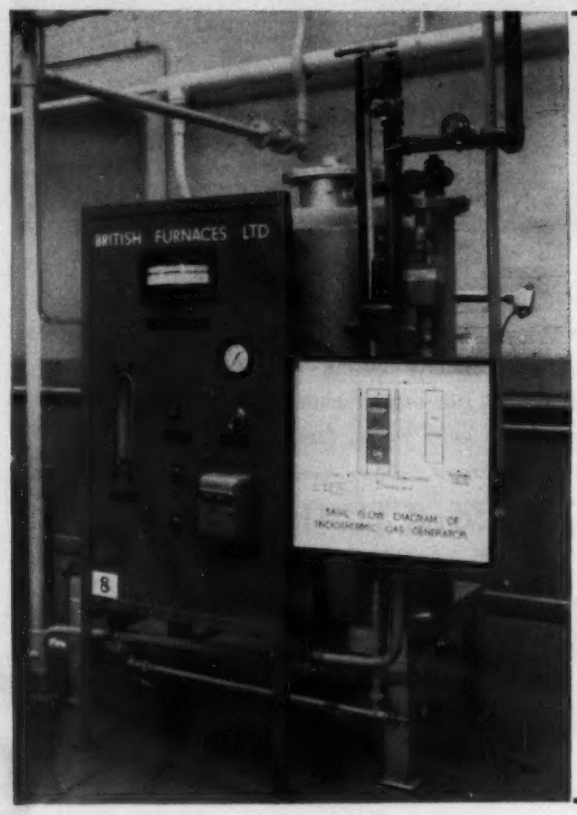

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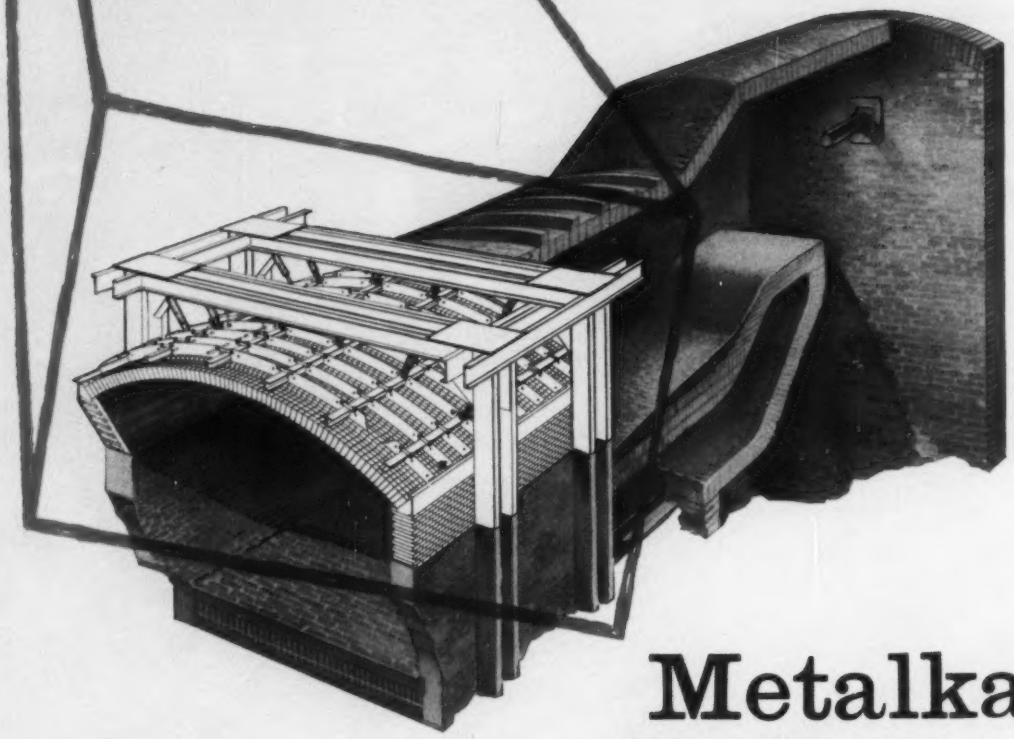

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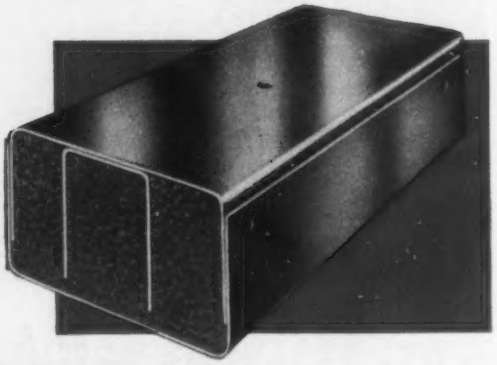

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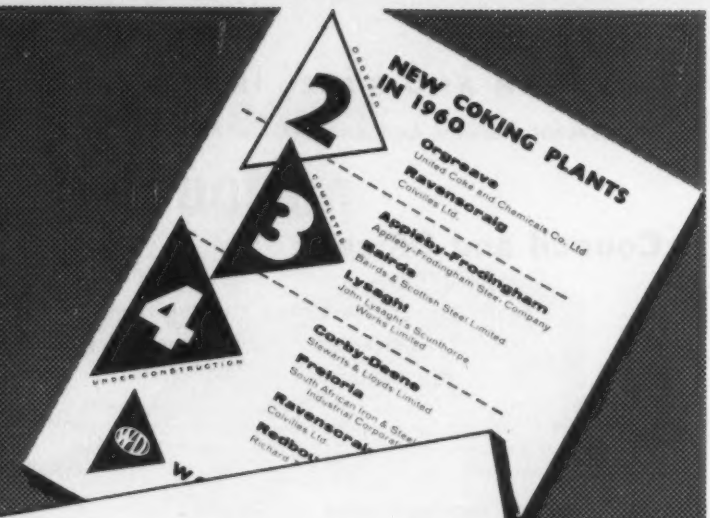

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Contents

THE IRON AND STEEL INSTITUTE

Report of the Autumn General Meeting 1960 — 269

The pre-refining of blast-furnace iron and development of the Brymbo oxygen/electric steelmaking process — 271
E. Davies

Application of flow research to industrial furnaces with particular emphasis on soaking pits — 283
H. Boenecke

Strain ageing and the fatigue limit of steel — 296
J. C. Levy and S. L. Kanitkar

Influence of local temperature increases on the fretting corrosion of mild steel — 301
R. B. Waterhouse

The solubility of silicon nitride in ferrite — 306
R. Rawlings and P. M. Robinson

The application of a digital computer to the pre-operational problems of programming the extraction and supply of iron ore — 309
H. I. A. Archibald

Obituaries: W. J. Dawson and L. Bouvier — 322

Education — 323

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

Sinter plant assessment trials at Guest, Keen Iron and Steel Co. Ltd — 313
J. McKelvie and G. Wilson

CORRESPONDENCE ON PAPERS

Surface effects occurring during the heating and cooling of plain carbon steels — 319
M. J. Olney and G. C. Smith

News 325 **Translations** 328 **Abstracts** 329

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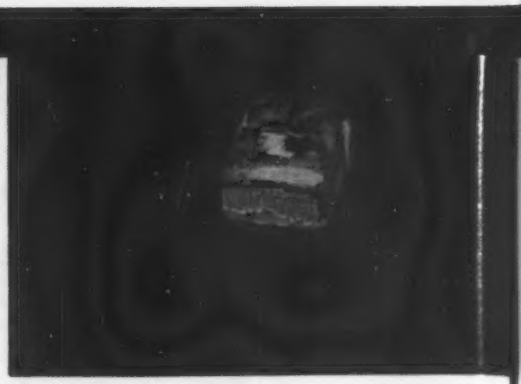

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GEORGE WILTON LEE is a grandson of Arthur Lee, the founder of Arthur Lee and Sons Ltd, Sheffield. He studied metallurgy, chemistry, and economics at Queens' College, Cambridge, before joining the family firm under the chairmanship of his father, the late Mr Percy Lee. In 1949 Mr Wilton Lee became chairman of Arthur Lee and Sons Ltd and shortly after he embarked on extensive modernization and expansion schemes which have since enabled the firm to meet greatly increased demands for stainless steel strip, wire, and bars.

While at Cambridge Mr Wilton Lee trained with the Territorials, and later he served as an officer with the 49th Division Royal Engineers. He was Master Cutler of Sheffield in 1950–1 and he is a Town Trustee of the city. He serves on the Executive Committee of the British Iron and Steel Federation and is chairman of the Light Rolled Steel Products Conference. A member of The Iron and Steel Institute since 1936, Mr Wilton Lee was elected a Member of Council in 1960.

G. Wilton Lee, T.D., J.P.
Member of Council

Autumn General Meeting, 1960

The Autumn General Meeting of The Iron and Steel Institute was held on Tuesday and Wednesday, 29 and 30 November 1960, at Church House, Great Smith Street, Westminster, London SW1, with the President, Mr W. F. Cartwright, in the Chair.

Minutes of the previous meeting

The minutes of the previous meeting held in London on 3 May 1960 were taken as read, and confirmed and signed.

Deaths

The President announced with regret the names of Members who had died. Among them were Sir Charles Bruce-Gardner who had been President in 1955–6, and had been associated for many years with the iron and steel industry and The Institute, and Dr E. G. Grace, a Bessemer Gold Medallist, and former President and Chairman of the Bethlehem Steel Corporation. Monsieur Charles Schneider had been one of the Institute's hosts during the meeting in France in 1956, and Professor P. Chevenard, a most distinguished metallurgist, had been a Member of the Institute since 1919. Mr K. A. F. Göransson and Professor N. P. Gandhi had also been exceptionally well known. Mr Barrington Hooper was among those who would be very much missed.

Those present stood in silence.

The Medal of the Iron and Steel Institute

The President announced that the Council, to commemorate the Tercentenary of the Royal Society, had decided to establish a new Gold Medal, to be known as The Medal of The Iron and Steel Institute, for presentation on special occasions to societies which, in the opinion of the Council, had rendered exceptional service to science or industry over a long period. The first award had been to the Royal Society. The second Medal had been presented to the Verein deutscher Eisenhüttenleute at their centenary celebrations in October 1960.

President-Elect

The President proposed, on behalf of the Council, that Sir Charles Goodeve, O.B.E., D.SC., F.R.S., be nominated for election as President, to take office at the Annual General Meeting in 1961 and to serve for one year. Sir Charles Goodeve had joined the Institute in 1945; he had become an Honorary Member of Council in 1945 and Vice-President in 1956.

Announcements

The Secretary (Mr K. Headlam-Morley) made the following announcements:

Changes on the Council since the last General Meeting in May 1960:

Vice-Presidents

Mr W. C. Bell
Professor A. G. Quarrell

Honorary Vice-Presidents

Major W. R. Brown, D.S.O.
Dr J. W. Jenkin
Mr T. Jolly
Mr N. H. Rollason

Members of Council

Mr M. A. Fiennes
Mr N. C. Lake
Mr G. Wilton Lee
Mr P. M. Thomas, D.S.O., T.D.

Hon. Members of Council

Mr R. Dingwall, President of the Cleveland Institution of Engineers, to succeed Colonel W. H. Mather.

Mr R. C. Powell, President of the Ebbw Vale Metallurgical Society, to succeed Mr W. B. Williams.

Dr E. Simister, President of the Leeds Metallurgical Society, to succeed Mr W. L. Bolton

Mr A. B. Ashton, President of the Manchester Metallurgical Society, to succeed Dr E. F. Emley.

Mr S. McLintock, President of the North Wales Metallurgical Society, to succeed Mr H. Edwards.

Mr F. V. Wright, President of the Staffordshire Iron and Steel Institute, to succeed Mr L. W. Law.

Mr M. J. A. Thomas, President of the Swansea and District Metallurgical Society, to succeed Mr D. W. Hopkins.

Dr W. O. Alexander and Dr N. P. Allen, F.R.S., to represent The Institution of Metallurgists in place of Mr W. E. Bardgett and Mr E. J. Bradbury.

Additional Hon. Members of Council:

J. Nutting
Dr W. S. Walker

Retiring Members of Council

The following were due to retire at the next Annual General Meeting and were eligible for re-election:

Vice-Presidents: Mr E. T. Judge, Mr F. H. Saniter, O.B.E., and Dr C. Sykes, C.B.E., F.R.S.

Members of Council: Mr R. A. Hacking, O.B.E., Mr E. W. Colbeck, Lt-Cdr. G. W. Wells, R.N., Mr T. R. Craig, O.B.E., T.D., and Mr P. E. Holloway.

Andrew Carnegie Scholarships

The following awards had been made since the last General Meeting:

£400 (Travelling Scholarship) to H. Holdhus (Technical University of Norway, Trondheim), to assist research on 'Phase equilibria in iron–silicon alloys, near the composition $FeSi_2$'.

£400 to W. D. Brentnall (Manchester University) (second grant) to assist research on 'Metallic meteor structures'.

£400 to K. Farrell (Sheffield University) (third grant) to assist research on 'Embrittlement of ultra-high tensile steels'.

£200 to T. B. Gibbons (Royal College of Science and Technology, Glasgow) (second grant) to assist research on 'Solubility and activity coefficient of CaS in the $CaO–Al_2O_3–SiO_2$ system'.

£450 to B. Walker (Birmingham University) (first grant) to assist research on 'Malleabilizing of white cast iron'.

Dates of Meetings in 1961

(i) Annual General Meeting in London, Wednesday and Thursday, 3 and 4 May 1961.

(ii) Special Meeting in the USA from 17 October to 8 November 1961.

(iii) Autumn General Meeting in London, Wednesday and Thursday, 29 and 30 November 1961.

Election of Members

Mr A. Stirling and Mr U. Notini, scrutineers of the ballot, reported the following elections:

Members

Alderson, Frederick Harry (Ascot); **Allen,** Norman, A.I.M. (Coventry); **Allen,** Thomas (Dudley); **Armitage,** Laurence James (Port Talbot); **Ates,** Franciscus Ferdinand (Amsterdam-Noord, Holland); **Atkinson,** M., B.SC.(ENG.)(MET.) (Port Talbot); **Beagrie,** Charles William Bowser (Sheffield); **Bernstein,** Lennart (Katrineholm, Sweden); **Bertrand,** Henri Marie Clair (Paris, France); **Bhargava,** Ram Dev, D.SC. (Bombay, India); **Bianchi,** Dr Giuseppe (Milan, Italy); **Bock,** Keith R., M.S.MET.ENG. (Fontana, California, USA); **Bradshaw,** Anthony Vernon, B.SC.(ENG.), A.R.S.M., M.I.M.M., F.I.M. (London); **Braithwaite,** Eric Reeves, M.SC., PH.D., F.PH.S., F.R.I.C. (Plymouth); **Buckland,** Peter Alan (Oviedo, Spain); **Burgess,** Douglas Onslow (London); **Burton,** Gordon David, A.M.I.MECH.E. (London); **Butterfield,** Michael Hughes, B.A. (London); **Cairney,** James M., PH.D., B.SC., A.R.C.S.T. (London); **Carter,** Anthony Brian, A.I.M. (London); **Caspersson,** Stig C. O. (Bofors, Sweden); **Chater,** William John, M.A. (London); **Chatterjee,** Rohini Mohan, B.SC. (Motherwell); **Clark,** Patrick Alwyne (Sheffield); **Clarke,** Herbert (Wolverhampton); **Collete,** Graham David (London); **Collins,** David (Motherwell); **Cooper,** C. Charles (West Bromwich); **Costley,** William Arnold (Coventry); **Cottrell,** A. H., M.A., B.SC., PH.D., F.I.M., F.R.S. (Cambridge); **Dowsing,** John, B.SC.(ENG.), A.C.G.I., G.I.MECH.E. (London); **Duckworth,** Walter Eric, M.A., A.I.M. (London); **Earl,** John Alexander, B.SC., A.M.I.E.E., A.M.I.MECH.E. (Manchester); **Edgar,** John, A.M.I.MECH.E. (Leeds); **Elphinstone,** Geoffrey Sydney (London); **Farmer,** Edward Ellis (London); **Farnsworth,** Walter B., M.S. (New York, USA); **Fasto,** Heinrich (Düsseldorf, W. Germany); **Feathers,** William H., B.S.(CHEM.ENG.) (New York, NY, USA); **Ferguson,** James, A.M.I.MECH.E. (Glasgow); **Finlayson,** Peter Campbell, B.SC., PH.D., A.M.INST.F. (London); **Fisher,** John Thomas (Port Talbot); **Foad,** Roland Walter (London); **Forster,** George Graham, A.R.C.S.T. (HONS.) (Workington); **Foster,** Reginald John, M.A. (London); **Franzen,** Alf Wilhelm (Björneborg, Sweden); **Gale,** Frederick John Gordon (Bristol); **Gibbons,** Vincent J., B.MET.ENG. (Fribourg, Switzerland); **Greenhaigh,** Harold (Milford); **Gunton,** Frank de la Roche, B.SC., A.M.I.E.E., A.M.I.MECH.E. (Rugby); **Guy,** Victor Harold, B.SC. (Sheffield); **Hall,** Richard C., PH.D. (Bridgeville, Pa, USA); **Hanson,** Albert, PH.D., M.SC. (Edmonton, Alberta, Canada); **Hargreaves,** Thomas Knowles, D.S.O., M.A., M.I.MECH.E. (Stockton-on-Tees); **Harries,** William Edwin Llewellyn (Ipswich); **Harris,** Crichton (Hereford); **Heller,** Frederick, B.A. (London); **Henry,** J. M. (Pompey (M. et M.), France); **Hessey,** Thomas, A.M.I.MECH.E. (Sheffield); **Hogg,** Arthur, M.SC. (Rotherham); **Holdom,** Ralph Thomas (London); **Honeycombe,** Robert William Kerr, PH.D., F.I.M. (Sheffield); **Howe,** Roy Duncalfe, L.I.M. (London); **Hughes,** Graham Bagnal (Port Talbot); **Hume,** Donald Allen (London); **Hunter,** Keith (Rotherham); **Hunting,** R. H., M.I.MECH.E. (Port Talbot); **Jamieson,** Robert, B.SC., A.M.I.MECH.E. (Cambuslang); **Jessop,** Brian Anthony, A.MET., A.I.M. (London); **Johnson,** Kenneth Vivian (Johannesburg, South Africa); **Johnstone,** James R., B.S.(E.E.) (New York, NY, USA); **Jones** Alexander Forsyth, B.SC.(HONS.) (Surbiton); **Josefsson,** Erik Anders Åke (Domnarvet, Sweden); **Kaveney,** Thomas F., B.S. (Cleveland, Ohio, USA); **Kaye,** Anthony Henry, B.MET., A.I.M. (Sheffield); **Kiessling,** Roland Richard, PH.D. (Stockholm, Sweden); **Lampmann,** Heinrich Albert (St Ouen (Seine), France); **Lazarus,** Alan A. (London); **Ledoux,** Louis Pierre, B.S. (Teaneck, NJ, USA); **Leser,** Hans-Georg, DIPL.-ING. (Leverkusen, Germany); **Leyshon,** Mervyn (Port Talbot); **Leach,** Gerald O. (Toronto, Canada); **Locke,** Philip Richard (Port Talbot); **Lockwood,** W. B. (Youngstown, Ohio, USA); **Lowrie,** Peter Lovell, B.SC., A.M.I.E.E. (Edenbridge); **Ludwig,** Matthias (Essen-Ruhr, Germany); **McCracken,** Alexander Brodie Allison (London); **McHendrie,** Henry Allan (Cambuslang); **McLean,** James Samuel (London); **McWilliams,** Thomas Grason, Jr. (Maryland, USA); **Marcer,** James Frederick (Sheffield); **Markland,** John Downes (London); **Martin Garcia,** José Tomás (Madrid, Spain); **Massart,** Joseph (Brussels, Belgium); **Maxwell,** Bernard, A.R.C.S.T., A.I.M. (Greenock); **Milne,** Robert Kerr Dunlop (Cambuslang); **Mitchell,** Eric, F.I.M. (Birmingham); **Moberg,** Ragnar W. (Degerfors, Sweden); **Montgomery,** Walter, A.M.INST.F., L.I.CERAM. (Brierley Hill); **Mossman,** Frank Andrew (London); **Muellenbach,** Wilhelm Joseph (Duisburg, Germany); **Mulvaney,** John (Blackheath); **Münch,** Günter, PH.D. (Leverkusen, Germany); **Needham,** Maurice Victor (London); **Negus,** James, B.SC. (London); **Nelsey,** John, B.SC., A.M.I.E.E. (Port Talbot); **Newby,** Frank, B.A., M.I.STRUCT.E., M.CONS.E. (London); **Nicholson,** William B., N.S. (New York, NY, USA); **Oddy,** Gilbert, A.M.I.MECH.E (Cardiff); **Ollila,** Leo W., B.S. (Irvine, Pa., USA); **Paige,** E. Stephen (London); **Painting,** Alfred Thomas (Durgapur Steel Project, District Burdwan, West Bengal, India); **Peacock,** David Robert, B.A.(HONS.) (London); **Pirie,** Charles William, A.I.M. (Newport); **Rambaud,** J. B. (Paris, France); **Rambaut,** Philip Marland, D.SC., M.A. (Carlisle); **Raper,** Reginald Froud (London); **Rassbach,** Herman P., B.S. (Cleveland, Ohio, USA); **Read,** Robert H. (Port Talbot); **Rees,** William Joseph, A.M.I.MECH.E. 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The **President** declared those candidates to be duly elected. They numbered 186, and the total membership of the Institute was now 5276.

Annual General Meeting 1961

The programme of the Annual General Meeting, to be held in London on **Wednesday and Thursday, 3 and 4 May,** is given on p.324 of this issue. The programme of the symposium on 'Structural processes in creep', which is being presented jointly with The Institute of Metals at parallel technical sessions of the Annual General Meeting, is given on the same page.

The pre-refining of blast-furnace iron and development of the Brymbo oxygen/electric steelmaking process

Emrys Davies

SYNOPSIS

This paper describes the early desiliconizing trials at Brymbo steelworks and the conditions under which dephosphorization can be achieved while retaining high carbon levels in the refined blast-furnace iron. Further trials carried out in a small open-hearth furnace and electric furnace bowl indicated the type of vessel most suitable for this operation. The pre-refining furnace removes the silicon and phosphorus from the molten pig iron. High silicon skulls and pit scrap are also melted during the process. The pre-refined hot metal is then used as 50% of the electric furnace charge. The development of this pre-refining technique has resulted in the practical and economic realization of the 'Brymbo oxygen/electric steelmaking process'.

1946

REVIEW OF EARLY WORK ON PRE-REFINING

THE ELIMINATION OF silicon and phosphorus from basic iron before charging into open-hearth furnaces has attracted the attention of steelmakers for many decades. The undesirable effect of high silicon, high phosphorus iron in the basic process is well known and in excess it is undoubtedly an unmitigated evil.

Pre-refining is not a new feature in steelmaking techniques. It is interesting to note the work done in this direction by Campbell in the USA and by Bertrand Thiel at Kladno in Bohemia and at the Hoesch Works in Germany. In 1890 in the USA, Campbell at Steelton, Pa., developed the 'washed metal' process.* This was carried out in the OH furnace, the hearth of which consisted chiefly of oxides of iron and lime. The hearth was not intended to last for several heats but was renewed with ore and lime after every heat. The washed metal furnace was not allowed to reach a high temperature and just sufficient time was allowed for the oxidation of the silicon and phosphorus. This practice was abandoned owing to the difficulty in maintaining the hearth and the heavy iron losses through chilled heats.

This was followed in 1897† at Kladno by the Bertrand Thiel process. Two OH furnaces were used for this process, one built on a higher level than the other, making it possible to tap from one furnace into another by means of a runner. The high level furnace was used to remove the silicon and most of the phosphorus and the process was completed in the second furnace from which the phosphoric–siliceous slag from the first furnace was excluded. This process was practised at Brymbo between 1900 and 1906 and it is on record that 40-ton charges were tapped within 4½ h. Typical examples of Bertrand Thiel heats are shown in Table I.

Some time later, at the Hoesch Works in Germany, the 'Hoesch process' was developed for treating iron high in silicon and phosphorus. Originally, two furnaces were used but later only one furnace was employed and worked the charge in two stages. A 50-ton furnace was charged with about 5 tons of scrap and a similar quantity of ore and 3–4 tons of lime. After heating the scrap and ore, about 40–42 tons of molten iron were charged. Reaction began immediately the hot metal was charged and was allowed to continue until all of the ore and the lime was melted and the slag fluid. By this means all the silicon and about half the phosphorus was eliminated and the carbon reduced to about 2·5%. The furnace was then tapped and the slag allowed to flow over the lip of the ladle. The furnace taphole was quickly closed (there being little or no fettling required) and a further 2–3 tons of scrap were charged together with about 2 tons of ore; 2 tons of lime and the refined iron were then charged into the furnace and worked in the usual manner, using fluorspar and scale to flux and shape up the slag. There was, however, a critical point in this process in that the firing of the furnace during the first part had to be carefully controlled to prevent excessive temperatures otherwise phosphorus reversion occurred. This process was worked for a short period on the NE coast but was eventually abandoned owing to difficulty in handling the ladles and holding the metal while closing the taphole, etc. The metallic yield of ingots was higher than direct working, owing to the more complete reduction of iron from the ore and yields up to 105% were usually obtained. This was superseded by the greatly superior

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* H. H. CAMPBELL: 'The manufacture and properties of Iron and Steel'; 1907, New York and London, McGraw Hill.
† BERTRAND THIEL: *JISI*, 1897, **1**, 122–123.

TABLE I Bertrand Thiel process, February 1901

	Hot metal composition, %					Slag composition, %		
	C	Si	Mn	P	S	SiO_2	P_2O_5	Fe
Heat A								
Primary furnace								
At charging	3·5	0·5	0·47	1·35	...			
1 h after charging	3·45	0·15	0·42	0·93	...	20·0	15·67	11·20
2 h 20 min after charging (Transferred to second furnace)	2·5	0·04	0·10	0·09	...	19·20	18·88	6·0
Secondary furnace								
1 h after transfer	0·35	0·02	0·05	0·02	...	14·66	9·7	18·0
2 h after transfer furnace tapped	0·15	0·02	0·32	0·01	...	13·00	4·9	13·5
Heat B								
Primary furnace								
At charging	3·5	1·30	0·39	1·25	0·025			
1 h after charging	3·5	0·31	0·20	0·99	tr	26·00	10·37	13·0
2 h 10 min after charging (Transferred to second furnace)	2·7	0·01	0·06	0·17	tr	24·33	15·83	6·0
Secondary furnace								
1 h after transfer	0·31	tr	0·10	0·02	tr	13·33	14·40	11·0
2 h after transfer furnace tapped	0·16	tr	...	0·02	tr	11·43	5·67	15·75

'Talbot process'. It will thus be seen that for over half a century attempts have been made to reduce the metallurgical load imposed on basic furnaces by high silicon and high phosphorus irons.

OBJECTS AND ADVANTAGES OF PRE-REFINING

It is probably true to say that a pre-requisite for high quality and maximum productivity in the basic OH process is physically hot metal of suitable composition together with regularity of that composition. For many years efforts have been made by OH operators to standardize the charges and 'start right'. In the words of a pioneer in this field 'You should mix your charge like an apothecary mixes his medicine and melt right; if you don't melt right, you never will be right'. All practical steelmakers are agreed on this point and it is the object of pre-refining to give this highly desirable 'start' to the process. An important advantage of a 'pre-refined start' is the simplification of slag control. In the basic steelmaking process the early slags formed after the addition of unrefined blast-furnace metal are usually highly acidic.

During this early period when the rate of metalloid elimination is at its maximum, slag basicity low and furnace oxidation rate high, there often arises an anomalous condition inasmuch as the early slags are low in FeO content. The inexperienced melter is thus tempted to speed up the process by making early additions of ore in an attempt to raise the FeO content of the slag and bring the charge on to an open boil. The result is that carbon ignition sets in before the silicon and phosphorus are removed to near specification limits, and frequently difficulty is experienced in making steels in the higher carbon range of 0·85% and above. This is because sulphur and phosphorus can only be fixed as calcium compounds and the addition of ore to a low basicity slag does not assist in this. The ore addition causes oxidation of the carbon in the bath with an accompanying boiling action which leads to considerable oxidation of the iron and if the deficiency of lime is not made good there will be bottom trouble as well as a soft melt. Many 'mysterious' causes of off-grade heats can be traced to this phase in the process and it cannot be over-emphasized that it is the melt-out condition and its treatment which determine the rate of oxidation of the metal and the ultimate quality of the steel. The burden of silicon and phosphorus in a charge using ordinary basic pig iron is not only high but, unfortunately, is variable and seldom accurately known so that the melter's task of judging and shaping up the melt-out slag becomes extremely difficult. By removing most of the silicon and phosphorus from the hot metal the incidence of melt-out troubles can be greatly reduced and a good basic slag formed early in the refining period. Furthermore, it is a well-known fact in basic steelmaking that heats produced under such highly basic, correctly controlled slags are freer from indigenous oxide inclusions.

During recent years the advent of tonnage oxygen and the new oxygen steelmaking processes has radically changed the picture and the importance of good primary slags low in SiO_2 content has become even more obvious.

Another important result of using pre-refined iron is that the lower slag volume leads to increased thermal efficiency and a reduction of the iron loss. A glance at the slag volumes required for hot metal charges using direct blast-furnace metal and pre-refined metal is interesting and the possibilities of working with reduced slag volume will appeal to every steelmaker (Table II).

DEVELOPMENTS AT BRYMBO

Shortly after the Second World War, when scrap was in short supply, the amount of blast-furnace iron used in the OH had to be increased. This inevitably raised the problem of carrying high slag volumes with consequent reduction in output. Efforts made to reduce the silicon content of the iron by adding scale, etc., to the

TABLE II Comparison of slag volumes arising from the use of (a) direct blast-furnace hot metal; (b) pre-refined hot metal

Type of hot metal						Furnace charge	Lime/ton, lb	Slag volume, %
Basic iron, %						50% hot metal 50% scrap	180	15·5
C	Si	P	S	Mn				
4·0	1·0	1·0	0·060	1·0		70% hot metal 30% scrap	220	19·6
Pre-refined iron, %						50% hot metal 50% scrap	50	4·5
C	Si	P	S	Mn				
2·0–2·5	0·10	0·1	0·05	0·25		70% hot metal 30% scrap	43	3·8

In calculating the above charges, no allowance is made for pickup of silica from furnace, i.e. an all basic furnace has been assumed.

TABLE III Ladle desiliconizing of blast-furnace metal

Blast-furnace metal		Highest, %	Lowest, %	Average, %
Before treatment with oxygen	Si	1·54	0·86	1·18
	Mn	1·55	1·25	1·43
	S	0·120	0·044	0·061
	P	1·05	0·62	0·82
After treatment with oxygen	Si	0·66	0·11	0·40
	Mn	1·30	0·70	0·94
	S	0·068	0·028	0·040
	P	0·98	0·47	0·71
Oxygen consumption (average), ft³/ton				315

TABLE IV Ladle desiliconizatien and dephosphorizatien of blast-furnace metal

Blast-furnace metal		Highest, %	Lowest, %	Average, %
Before treatment with oxygen	Si	1·04	0·70	0·90
	Mn	1·40	1·05	1·20
	S	0·080	0·032	0·052
	P	0·85	0·56	0·70
After treatment with oxygen	Si	0·10	tr	tr
	Mn	0·36	0·15	0·26
	S	0·046	0·016	0·036
	P	0·200	0·070	0·106
Oxygen consumption (average), ft³/ton		1525		

blast-furnace runners and ladles were unsatisfactory. The situation was changed in 1948 when, in conjunction with BISRA, oxygen was used to desiliconize blast-furnace iron. It was found that comparatively small quantities of oxygen, some 350–450 ft³/ton were sufficient to reduce the silicon content from 1·2% to about 0·4% (Table III). Thus a method for rapid desiliconizing was established which shortly afterwards became standard practice at Brymbo, a pattern later followed by many steelworks in the UK and abroad.

At that time oxygen was expensive and progress in applying the process was therefore slow. Not until 1951 was it possible to store the large quantities necessary to operate the process on a full production scale. For this purpose, a satellite plant was installed housing four evaporators, each capable of supplying 48000 ft³ of gaseous oxygen. This process was carried out in 30-ton ladles and was later developed to remove not only the silicon but also the phosphorus and it became clear that, providing the reactions proceeded mainly via the slag, as in the OH process, the phosphorus could be eliminated while the carbon was retained at high levels, i.e. 2·0% and above.

It is virtually impossible to obtain optimum results in an open ladle, but it was by virtue of the results obtained during the early work on desiliconizing that the full significance of the process was realized. Even under such crude conditions it was clear that part of the phosphorus could be removed during the desiliconizing operation (Table IV). As indicated previously, the need for early slag formation was obvious and it was during this period that trials were carried out making progressive additions of granulated slag-forming materials during blowing.

At this stage the Brymbo process crystallized and the way became clear for using large quantities of pre-refined blast-furnace hot metal not only in the OH but also in the electric arc furnaces. This fitted in perfectly with the company's ideas for the new development scheme, because unlike other steelworks which have installed large new electric furnaces to work the conventional 100% scrap process, Brymbo wished to continue the operation of the blast-furnace, and consequently it was essential to find a method of making the hot metal suitable for refining in the new arc furnaces. The reason is that the electric furnace is not well adapted to undertake the refining of large quantities of molten iron. Unlike the OH which maintains an oxidizing atmosphere over the charge, the arc furnace treats the metal in a more or less sealed-off chamber, in an atmosphere which is virtually non-oxidizing and which can be made reducing if desired. The result is that to refine regularly silicon, phosphorus, and more than 2½%C from molten metal in an electric arc furnace is difficult both metallurgically and practically. The action is slow and the quantity of basic slag which is necessary to 'fix' the phosphorus could cause severe wear on the electrodes. High consumption of electric power, the most expensive item in electric furnace practice, makes the entire operation uneconomic.

As indicated previously a ladle is not a suitable vessel in which to carry out both desiliconizing and dephosphorizing. Slopping and foaming occur when the silicon content of the iron exceeds 0·5%, slagging-off is difficult, and the whole process is messy and undesirably long. Before finalizing the design of the pre-refining furnace further trials were carried out in a small OH furnace. Much improved results were obtained by dispensing the slag forming materials, chiefly powdered lime and limestone, with the oxygen stream. It also became evident that in the oxygen process the control of the phosphorus becomes more difficult as the reactions are accelerated if the silicon of the iron is high and the bath temperature rises rapidly in consequence. Because of this the influence of silicon and the control of the temperature during the early stages of pre-refining is of paramount importance. Since this operation is completed within 15–20 min of starting to blow the need for early slag formation and close temperature control is obvious. This can be adjusted by making suitable additions of scrap or ore or both. The advantage of ore additions with the charge is to facilitate early slag formation and again, as there is a certain minimum Fe content of the slag required by existing conditions, it is better to add this in the form of ore rather than at the expense of oxidized metal from the bath. In this way most of the ore added will give a clear gain in yield. The effect of ore is, therefore, twofold: it is an excellent cooling medium and promotes liquefaction of the lime ensuring early slag formation which favours dephosphorization. It would appear that when the ore comes into contact with the liquid iron it is immediately reduced to liquid ferrous oxide, providing that the temperature is above 1400°C which is just above the melting point of FeO.

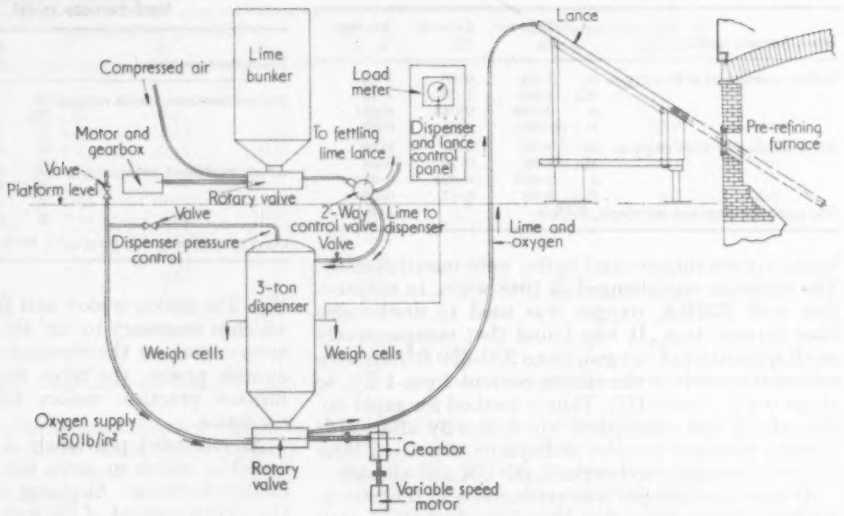
The phosphorus reaction then proceeds in the following direction:

$$2\,(P)+8\,(FeO)-3FeO,\,P_2O_5)+5\,Fe$$

but cannot proceed far towards the right unless lime is available to react with the orthophosphate as follows:

$$(3\,FeO\,P_2O_5)+3\,CaO=(3\,Cao\,P_2O_5)+3\,FeO$$

The addition of crushed lime and/or the injection of lime powder with the oxygen stream facilitates this reaction and it will be seen that, providing the above



1 *Cross-section of pre-refining furnace, no.2 electric melting shop*

conditions are observed, the phosphorus can be removed simultaneously with the silicon and carbon.

When treating iron high in silicon, i.e. 1·0% and above, it is better, and indeed standard practice at Brymbo, to flush off the siliceous slag after a short blow using 400–450 ft³ of oxygen per ton, which is sufficient to reduce the silicon from 1·5% to below 0·5%, leaving only sufficient slag to assimilate further lime additions. At this stage the dispensing of the lime with the oxygen is most beneficial, and the incidence of foaming is reduced until carbon ignition sets in when considerable foaming occasionally occurs. While foaming is usually an indication of early phosphorus removal its mechanism of reaction is somewhat obscure.

It is clear that the time and extent to which phosphorus passes into and is fixed in the slag depends largely on the timing of the carbon reaction. If this begins early during the blow the phosphorus reaction is retarded and it may well be that temperature plays a very important part in this, local high temperature zones could 'trigger off' the carbon reaction at an early stage in the blow, the reaction being in the gas, metal, slag, phase. On the other hand several heats have been made and the phosphorus completely eliminated while the carbon content remained high, i.e. above 2·0%. In all such cases the primary conditions had been fulfilled, i.e. a highly basic slag and sufficient FeO present to ensure fixation of the P_2O_5.

These trials confirmed the feasibility of the Brymbo process for the use of blast-furnace iron in electric furnaces.

DESIGN AND DEVELOPMENT OF THE PRE-REFINING FURNACE

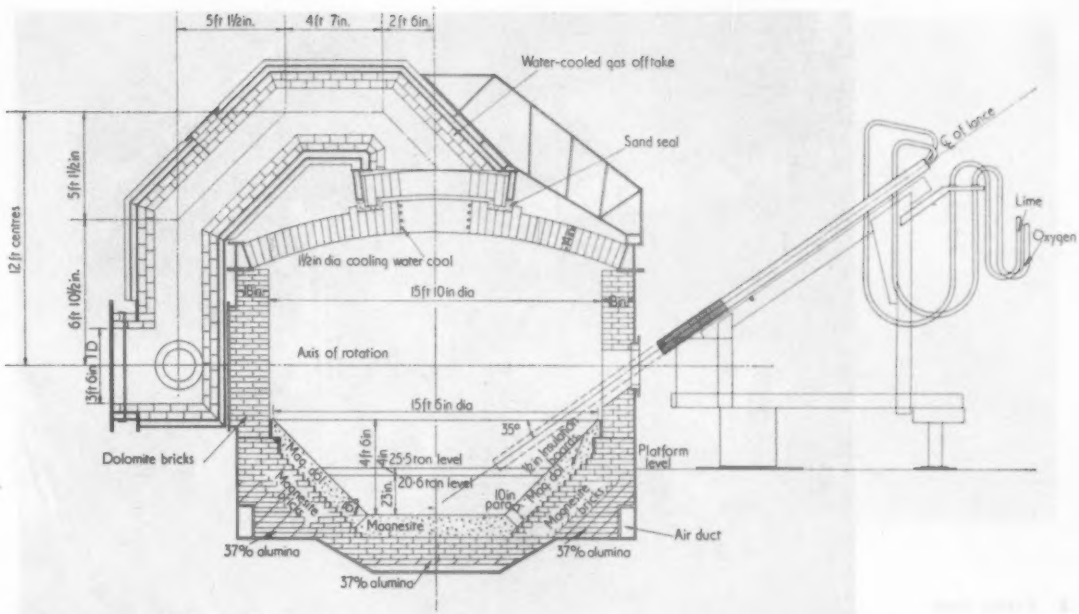
The only remaining problem was the design of a suitable furnace or vessel within which this process could best be worked practically and economically. The importance of adequate slag/metal surface area was evident and it was desired to obtain sufficient bath agitation without having to incorporate means for rotating the hearth. Provision for fume extraction and the control of foaming and frothing had to be considered and the choice of suitable refractories was important. It was desirable that the vessel could be fettled, when required, between heats and provision made for burning-in such fettling material, as well as the initial burning-in of the hearth.

TABLE V Pre-refiner, 1st campaign, 565 heats Weeks ending 4 April 1959 to 18 July 1959

	Blast-furnace hot metal		Scrap used					Consumption/ton			
	Total	% of charged weight	Total	% of charged weight	Total charged weight	Pre-refined hot metal produced	Yield, %	Oxygen 100%+ efficiency	Lime	Fettling dolomite	Sidewall dolomite
	Long tons		Long tons		Long tons	Long tons		ft³	lb	lb	lb
Total	12094	96·5	441	3·5	12535	11608	92·6	887	106	22	0·48
Per heat	21·40		0·78		22·18	20·54					
	Metric tons		Metric tons		Metric tons	Metric tons		nm³	kg	kg	kg
Total	12288		448		12736	11794		25	48	10	0·22
Per heat	21·75		0·79		22·54	20·88					

Hearth, side-wall, and roof life	*No. of heats*	*Refractory consumption/ton* lb	kg
Hearth	685*	5·98	2·71
Side-walls	565†	7·42	3·37
Roof	175	13·88	6·30

* During February and March 1959 the furnace was in commission and 2049 tons of pre-refined hot metal was produced from 120 heats. The side walls were relined after these heats.
† This figure includes one major repair after 232 heats and considerable gun patching.



2 *Arrangement of dispensing equipment*

As this furnace would be installed inside the new melting shop and adjacent to the electric furnaces it was obvious that it should not have an open top similar to the conventional converter or LD vessel. The roof, therefore, should be portable and roof changing should not present any serious problem. Lance position and the installation of oil burners to deal with foaming and keep the slag open after blowing had ceased, were other features to be considered. To ensure the high temperature necessary to burn-in the hearth lining it was decided to enrich the combustion air with oxygen tapped off the main supply, thus attaining flame temperature of about 2000°C. This has been achieved in a unique manner. The duct carrying the combustion air passes inside the furnace and under the hearth brickwork, giving a twofold effect: a small measure of superheat is obtained and the sub-hearth is cooled by the constant flow of air through the ducts. Oxygen enters the duct at a point below the secondary air fan.

After considerable discussion with furnace construction experts and further trials in an electric furnace bowl, the latter vessel was decided upon because it offered greater flexibility than the rectangular OH bath; also the advantages of roof changing, charging, and fettling were obvious. The two remaining problems were the removal of fume and the control of foaming and frothing of the slag during the reaction. For fume removal, in the original design, the fume off-take was centrally placed opposite the water-cooled lance and raised to a position just below the roof, which was extensively water cooled. During the first campaign this proved (not unexpectedly) to be the weakness of the process and was later changed to a position in the centre of the roof. The advantages of this change have been enormous as will be seen from the comparative records of both campaigns (Tables V and VI).

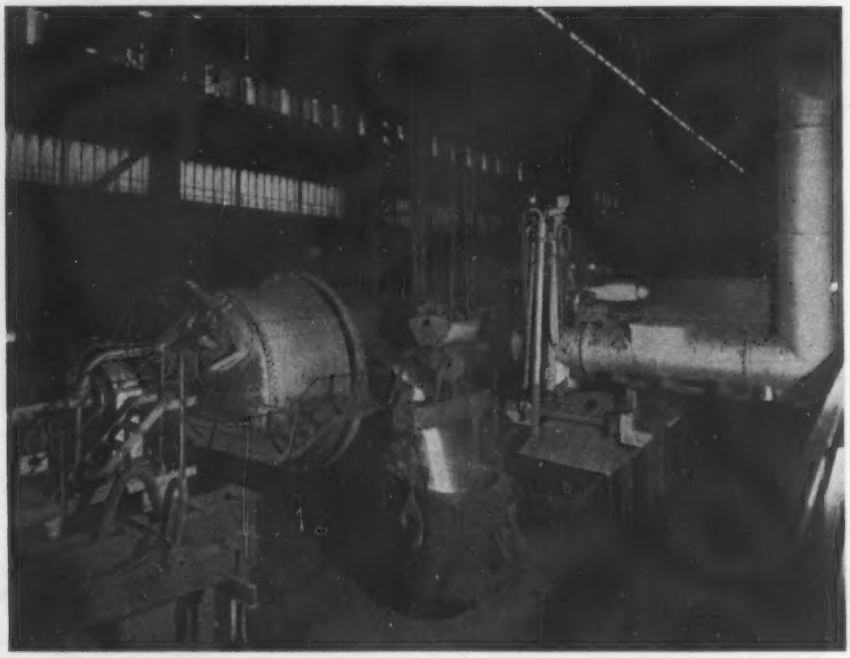
To control the foaming slag, the hearth was deliberately made deep, 4 ft 10 in to sill level, and in addition

TABLE VI Pre-refiner, 2nd campaign, 2480 heats Weeks ending 23 January 1960 to 31 December 1960

	Blast-furnace hot metal		Scrap used					Consumption/ton			
	Total	% of charged weight	Total	% of charged weight	Total charged weight	Pre-refined hot metal produced	Yield, %	Oxygen 100%+ efficiency	Lime	Fettling dolomite	Sidewall dolomite
	Long tons		Long tons		Long tons	Long tons		ft³	lb	lb	lb
Total	52712	90·7	5396	9·3	58108	53924	92·8	900	85	2·67	0·17
Per heat	21·25		2·18		23·43	21·74					
	Metric tons		Metric tons		Metric tons	Metric tons		nm³	kg	kg	kg
Total	53556		5482		59038	54787		25·3	39	1·21	0·08
Per heat	21·60		2·21		23·81	22·09					

Hearth, side-wall, and roof life	*No. of heats*	*Refractory consumption/ton* lb	kg	
Hearth	2480	2·71	1·23	continuing
Side-walls	1391	3·59	1·63	
Roof	170	10·31	4·68	

Notes: (*a*) Recent trials have indicated that the yield may be understated by ½–1%.
(*b*) The scrap usage is the average for the campaign but a maximum of 25% has been achieved.



3 *Taking blast-furnace metal from the receiver*

the oil burners were incorporated and mounted tangentially in the walls. As indicated previously the air supply is passed under the furnace hearth to obtain a degree of pre-heat (and to cool the hearth at the same time) and in addition this air can be enriched with oxygen tapped off the main supply. The intensely hot flame again serves a dual purpose by 'knocking' down the foam and at the end of the process, should any delay occur, by keeping the slag 'open' until tapping is completed. The effect of this on the Fe content of the slag is interesting. A cross-section of the furnace is shown in Fig.1.

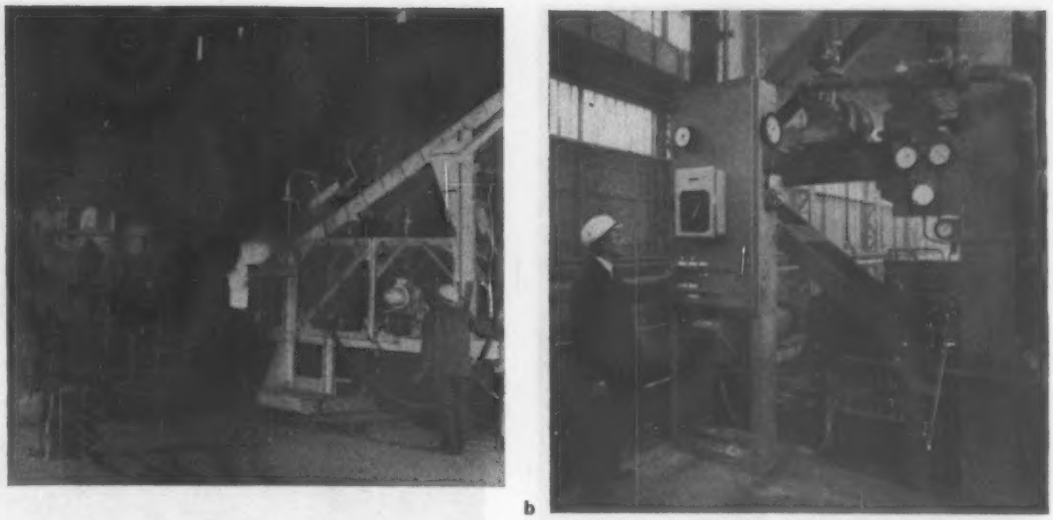
The hearth is 16 ft dia. giving roughly 6 ft^2/ton of iron and the vessel is capable of treating up to 30-ton batches of iron. The whole vessel rests on rockers and rollers, facilitating tilting to angles of 20° for slagging and 40° for tapping. The axis of tilt is so arranged that at all angles the water-cooled duct for removing fume and products of combustion remains in full operation. Fume-cleaning plant will be installed shortly.

Furnace refractories

For the first campaign it was decided to install a graded tarred-dolomite hearth above the magnesite sub-hearth with sidewalls in tarred dolomite bricks. The area adjacent to the taphole was in magnesite and the taphole formed and moulded with 'Doloset'. High alumina (65%Al_2O_3) bricks were chosen for the roof and part of the fume off-take. (Two silica 'crown' roofs were tried with disastrous results, lives of only 20–25 heats being obtained.)

4 *Charging scrap from pre-refiner*

5 *Charging hot metal into pre-refiner*



6 (*a*) *Oxygen lancing (showing water-cooled lance immersed)* and (*b*) *lime dispenser control panel*

From the experience gained during the first months of operation it became obvious that dolomite was not a suitable hearth material. The next installation was made up of 9 in graded Britmag vibrated in a well-consolidated layer above the mag-brick sub-hearth, above this a layer 3 in thick of magnesite-enriched dolomite in the proportion of 25% magnesite and 75% dolomite both finely graded and again consolidated with a vibratory roller. The banks were made of this same material and the results have been highly satisfactory, as the records indicate (Table VI).

Injection of oxygen and lime

Oxygen for the pre-refining operation is injected into the metal through a water-cooled lance, specially designed for this purpose by HOAG, Germany. Originally, two water-cooled lances of a different type were installed but were discarded owing to lance failures and excessive erosion of the banks in the taphole area. The Oberhausen lance enters the furnace on the axis of tilt and so can operate while the furnace is tilted in any position. It is thermostatically controlled. Various types of nozzles are being experimented with, but a single nozzle oxygen/lime jet has proved highly satisfactory and has been in operation for 964 heats. These nozzles are replaceable and can be easily welded up and repaired in the event of leaks. The nozzle fins or serrations are coated with magnesite slurry for the first heat, following which slag becomes keyed into the fins and thus affords adequate protection when the lance is immersed into the metal bath. Oxygen is injected into the bath at about 1250–1400 ft^3/min or 50–56 ft^3/ton/min.

Lime dispensing

During the trial period of lime dispensing, various mixtures of powdered lime and limestone were tried before the ideal combination was evolved. It was found that the dissociation when using pure ground limestone caused excessive gas off-take temperatures, whereas pure powdered lime 'packs' in storage, making it extremely difficult to entrain in the oxygen

7 *Bath showing 'boil' after completion of blow and before slagging-off*

8 *Slagging-off*

10 *Tapping pre-refiner, finish of tapping operation showing furnace fully tilted*

stream. Eventually, a mixture containing 75%CaO and 25%$CaCO_3$ was adopted, this material giving efficient flow properties, at a grading of all $-\frac{1}{8}$ in.

The powdered lime–limestone mixture is fed into two 3-ton capacity dispensers from storage bunkers; it is mechanically fed into these bunkers from road transport 'tankers' and is again pneumatically transferred into the lime dispensers. The material is metered into the lance and the dispensers placed on load cells; a recording indicator checks the amount being injected. This can be varied between 40 and 400 lb/min and is controlled by a variable speed motor, again pre-set and controlled from the operators panel on the melting shop stage. The system shown in Fig.2 was designed and built by the Yorkshire Engineering and Welding Co. Ltd. who have had many years of experience in this field. Erosion troubles of piping leading to the

9 *Tapping pre-refiner*

11 *Transferring pre-refined metal into charging bay*

12 *Charging pre-refined hot metal into 40-ton arc furnace*

lance have been overcome by using special tubing for the fixed and flexible connecting hoses.

OPERATION OF THE PRE-REFINING FURNACE

The log sheet of a heat is given in Table VII. Briefly the procedure is as follows. Blast-furnace metal, stored in a small inactive receiver of some 200 tons capacity, is charged as required into the oxygen refining furnace. Before adding the hot metal, high silicon pit scrap (up to 4·0%Si content) and crop ends are charged by a floor charging machine into the furnace. By this means this highly siliceous scrap (generally unwanted in the basic process) can be usefully melted up and recovered. One third of the crushed lime ($\frac{1}{2}$–$1\frac{1}{2}$ in lumps) is added and the required amount of ore spread over the lime.

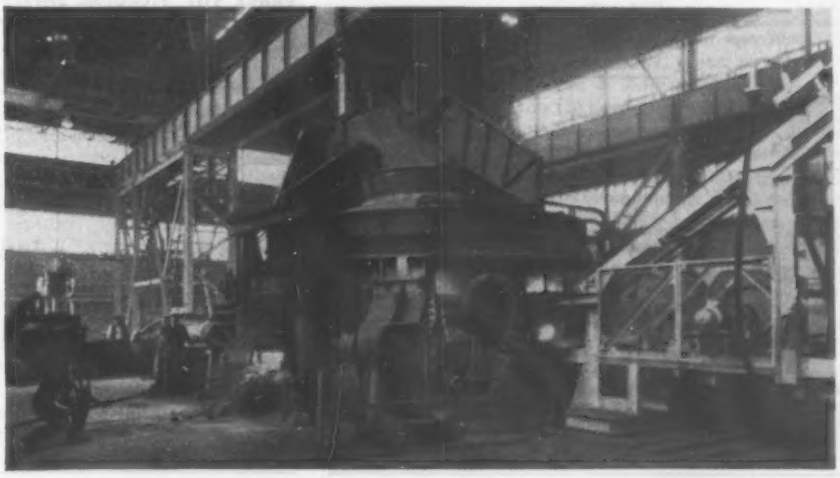
The hot metal, 20–25 tons, is then poured down a portable trough into the furnace and the furnace pressure checked. Immediately afterwards a $\frac{3}{4}$ in dry

14 *View of lime dispensing equipment*

lance is inserted over the 'sill' and oxygen injected at 600 ft³/min for about 3 min. This is sufficient to form the slag pool necessary to protect the large water-cooled lance nozzle, so that only a small amount of dry lance is consumed in this operation.

The need for this preliminary 'blow' may be debatable, but experience has shown that it is a well-tried precautionary measure and ensures protection for the main lance which follows into the furnace immediately the dry lance is removed. Failures and troubles with the main water-cooled lance have occurred only when this precautionary measure has been ignored and, as little or no time is lost, the small amount of dry lance consumed is amply repaid in long periods of trouble-free blowing with the main lance.

Oxygen is now injected into the metal at 1250 ft³/min and after a period of about 5 min the dispenser is started up. The amount of lime charged and dispensed will, of course, vary according to the Si content of the iron, and as previously indicated when this exceeds 0·85%Si a preliminary desiliconizing blow is carried out, the siliceous slag being flushed off and more lime charged or dispensed. The oxygen/lime blowing



13 *Fettling with lime powder*

15 *View of lime dispensing (below stage) showing variable-speed motor*

16 *View below stage showing air ducting and oxygen equipment*

continues for a pre-determined period, after which the lime dispensing is stopped (by pressing a button) and oxygen blowing continued. The total blowing time averages 20 min, which is a considerable improvement on the first campaign when dry lances were used practically throughout.

During the blowing operation the furnace pressure is carefully checked and only sufficient 'draught' allowed to keep the furnace clear of dense fumes. No attempt is made to burn the CO evolved during the carbon reaction to CO_2, and waste-gas analyses confirm the possibility of heat recovery. When the bath carbon is in the desired range, samples of metal and slag are taken and the temperature is checked with the immersion pyrometer. Owing to the high carbon content (2·0%) it is quite unnecessary to carry high bath temperatures and rarely are these allowed to exceed 1550°C, which allows ample time for tapping and transferring to the electric furnaces. Even in the event of mechanical or other delays skulled ladles are a very rare occurrence and this is a great advantage in comparison with other converter processes.

The pre-refined metal is used as 50% of the electric furnace charge and always contains sufficient carbon to ensure adequate melt-out carbon to make final decarburization in the electric furnace (using the oxygen lance) simple and rapid. Another feature is that at this stage the iron oxide content of the slag can be kept at quite a low level, making the overall metallic recovery high.

TABLE VII Typical pre-refiner log sheet

Charge	tons	cwt
Blast-furnace metal	20	10
2%Si mill crops	2	11
	23	1

Furnace log

6.05 pm	Scrap charged
6.20 pm	Blast-furnace metal charged
6.25 pm	8 cwt lime charged
6.30 pm	500 ft³ oxygen blown with consumable lance
6.35 to 6.55 pm	19500 ft³ oxygen blown at 1000 ft³/min with water-cooled lance 8 cwt powder lime dispensed
7.00 pm	Furnace slagged
7.05 pm	Furnace tapped

Analysis, %

	C	Si	Mn	S	P	Metal temp., °C
Blast-furnace iron	3·91	0·93	0·72	0·060	0·40	1260
Pre-refined iron	1·80	...	0·12	0·048	0·082	1565

	SiO_2, %	Fe, %	CaO, %	P_2O_5, %
Tapping slag	16·0	12·6	40·0	6·5

Weight of refined metal	21 tons 9 cwt
Yield	93%
Oxygen used	935 ft³/ton refined metal
% scrap melted	11
Lime	85 lb/ton refined metal

TABLE VIII Pre-refiner, average materials used

	% of total burden	Per ton of pre-refined metal cwt	kg
Burden			
Blast-furnace hot metal	90·46	19·43	987·04
Own scrap	9·54	2·05	104·14
Actual yield, 93·1%	100·00	21·48	1091·18
Oxides		lb	
Ore		23·67	10·74
Scale		2·50	1·13
	Total	26·17	11·87
Fluxes			
Lime		85·00	38·56
Limestone		2·50	1·13
Fluorspar		2·50	1·13
	Total	90·00	40·82
Fettling materials			
Dolomite		2·67	1·21
Coke breeze		0·50	0·23
Oxygen		900 ft³	25·3 nm³
Fuel oil		3 gal	13·64 l
Dry lances 1½ lances per heat		1 ft	0·305 m

TABLE IX Ideal electric furnace hot metal charge, En45 quality

Specification

C	Mn	Si	S	P
0·55–0·60	1·8–2·0	0·80–1·00	0·040 max.	0·040 max.

Charge

	tons	cwt
Scrap	24	6
Pre-refined metal	23	8
	47	14
% hot metal	49	

Furnace log

9·05 pm	Previous heat tapped
9·35 pm	Power on
10·25 pm	Hot metal charged + 25 cwt ore + 45 cwt lime
11·15 pm	Clear melt

Analysis, %

	C	Mn	S	P		Fe	CaO	SiO_2
Metal	0·84	0·18	0·047	0·019	Slag	13·6	44·2	12·4

6 500 ft³ of oxygen at 500 ft³/min blown + 11 cwt lime

11·40 pm	Temperature 1 590°C

Analysis, %

	C	Mn	S	P		Fe	CaO	SiO_2
Metal	0·56	0·18	0·040	0·016	Slag	9·7	50·0	10·0

12.05 am	Furnace tapped

Final analysis, %, pit sample

C	Si	Mn	S	P
0·58	1·96	0·88	0·038	0·023

Metallic yield, % 95

Consumption

Electricity	337 units ingot ton
Lime	142 lb/ingot ton
Oxygen	150 ft³/ingot ton

Total heat time, tap to tap, 3 h

TABLE X Typical electric furnace log, En16 quality

Specification

C	Mn	Si	S	P	Mo
0·33–0·38	1·4–1·6	0·30 max.	0·040 max.	0·040 max.	0·20–0·30

Charge

	tons	cwt
Scrap	26	11
Pre-refined metal	22	0
Total	48	11
% hot metal	45·5	

Furnace log

11·50 am	Previous heat tapped
12·20 pm	Power on
1.20 pm	Hot metal charged + 25 cwt ore + 40 cwt lime
2.20 pm	Clear melt

Analysis, %

	C	Mn	S	P	Mo		Fe	CaO	SiO_2
Metal	0·88	0·131	0·036	0·020	0·02	Slag	14·0	47·7	12·0

Calcium molybdate added + ferromanganese

10 000 ft³ of oxygen blown at 500 ft³/min

4.15 pm	Temperature, 1 630°C

Analysis, %

	C	Mn	S	P	Mo		Fe	CaO	SiO_2
Metal	0·335	0·23	0·031	0·010	0·24	Slag	12·0	48·7	10·2

4.25 pm	1 200 lb ferromanganese added to bath
4.45 pm	Furnace tapped

Final analysis, pit sample

C	Mn	Si	S	P	Mo
0·38	1·47	0·30	0·030	0·016	0·24

Metallic yield, % 94·5

Consumption

Electricity	400 units/ingot ton
Lime	124 lb/ingot ton
Oxygen	255 ft³/ingot ton

Total heat time, tap to tap, 4 h 55 min

Fettling of the furnace between heats is carried out in a unique manner. Lime powder dispensed at a pressure of 2 atm is pneumatically injected direct from a bunker on to the sidewalls, banks, and hearth of the furnace. The maximum delivery rate of lime powder is 1 cwt/min. This is carried out when the furnace is at a high temperature and the banks and walls in a 'tacky' to wet condition, thus facilitating the fixing of the lime. By this means the linings are protected and indeed built up in an economical and convenient way so that fettling is greatly simplified and considerable savings in dolomite effected. In order to maintain the high furnace temperature necessary during lime spraying, the oxygen/oil burner is turned on for a short period. The consumption of fettling dolomite during the six months (January–July) campaign was only 3·8 lb/ton as against 22 lb/ton on the previous campaign.

The protection afforded to the sidewalls is indicated by the phenomenal life of 1 390 heats. With the hearth remaining in excellent condition production was continued on the old bottom, renewal being unnecessary, but the top of the banks were built up with tarred graded dolomite forming the foundation for the 18 in dolomite sidewalls.

The average blowing time is 20 min for a carbon content of 1·5% and 15 min for the higher carbon ranges, the oxygen efficiency is 100% plus and the average metallic yield 93%.

One of the additional advantages of the use of the pre-refiner, which may not be evident at first sight, is its ability to absorb quantities of large-sized and awkwardly shaped scrap. Large lumps of pit scrap cannot be satisfactorily melted in the electric furnace because they tend to cause electrode breakages, in the pre-refining furnace they are melted easily and cheaply. Table VIII gives the average burden of the pre-refiner showing the quantities of scrap absorbed and refining materials used.

ELECTRIC STEELMAKING

As indicated previously the pre-refined metal is used as 50% of the charge to the electric furnaces. After removal from the pre-refiner the hot metal is transferred to one of the 40-ton electric arc furnaces in which the scrap has already been charged and heated, and as power has been on the arc furnace for only 20–25 min it is thus possible to keep the power on the furnace while charging the hot metal. This greatly restricts the tendency to surge and facilitates smooth operation at maximum power input and reduces the incidence of electrode breakages. Typical examples of hot metal heats are shown in Tables IX–XII.

Thus it will be seen that by increasing the amount of pre-refined metal in the charge, considerable economies in power consumption and electrodes can be effected, the average electrode consumption on 50% hot metal charges being 8 lb/ingot ton. For steel made in this way the electric power consumption ranges between 230 and 400 kWh/ton depending on the amount of hot metal in the charge. The best heat time obtained has been about 2 h for a 48-ton charge (and 85% hot metal) consuming 230 kWh/ton.

CONCLUSIONS

After one year's operation the advantages of the hot metal process have been adequately proved for the production of special forgings and low alloy steels. The main advantages are:

TABLE XI High percentage hot metal heat, En45 quality

Specification, %

C	Mn	Si	S	P
0·55–0·60	0·80–1·00	1·8–2·00	0·040 max.	0·040 max.

Charge

	tons	cwt
Scrap	7	4
Pre-refined metal	41	4
Total	48	8
% hot metal	85	

Furnace log

3.25 pm	Previous heat tapped
3.45 pm	Scrap charged
3.50 pm	Power on
4.15 pm	1st ladle of pre-refined metal + 45 cwt lime
5.25 pm	2nd ladle of pre-refined metal
5.45 pm	Clear melt

Analysis, %

	C	Mn	S	P		Fe	CaO	SiO_2
Metal	0·91	0·28	0·053	0·025	Slag	11·0	49·3	9·4
			9000 ft³ of oxygen blown at 500 ft³/min					
6.25 pm			Temperature, 1580°C					

Analysis, %

	C	Mn	S	P		Fe	CaO	SiO_2
Metal	0·50	0·20	0·042	0·016	Slag	9·6	50·2	9·0
6.50 pm			Furnace tapped					

Final analysis, %, pit sample

C	Mn	Si	S	P
0·59	0·97	1·89	0·037	0·025

Metallic yield, % 94

Consumption

Electricity	178 units/ingot ton
Lime	140 lb/ingot ton
Oxygen	200 ft³/ingot ton

Total heat time, tap to tap, 3 h 25 min*

* Includes 1 h 10 min between ladles of pre-refined metal.

TABLE XII High percentage hot metal heat, En8 quality

Specification, %

C	Mn	Si	S	P
0·33–0·38	0·70–0·80	0·30 max.	0·040 max.	0·040 max.

Charge

	tons	cwt
Scrap	8	5
Pre-refined metal	42	11
Total	50	16
% hot metal	84	

Furnace log

6.35 pm	Previous heat tapped
6.55 pm	1st ladle of pre-refined metal + 40 cwt lime + scrap
7.05 pm	Power on
8.05 pm	2nd ladle of pe-refined metal
8.25 pm	Clear melt

Analysis, %

	C	Mn	S	P		Fe	CaO	SiO_2
Metal	0·64	0·46	0·041	0·042	Slag	9·0	51·0	13·2
			5600 ft³ of oxygen blown at 500 ft³/min					
9.20 pm			Temperature, 1620°C					

Analysis, %

	C	Mn	S	P		Fe	CaO	SiO_2
Metal	0·36	0·28	0·030	0·030	Slag	8·5	50·0	11·8
9.45 pm			Furnace tapped					

Final analysis, %, pit sample

C	Mn	Si	S	P
0·37	0·77	0·27	0·027	0·035

Metallic yield, % 95·5

Consumption

Electricity	230 units/ingot ton
Lime	125 lb/ingot ton
Oxygen	120 ft³/ingot ton

Total heat time, tap to tap, 3 h 10 min*

* Includes 1 h waiting between ladles of pre-refined metal.

1. Increased production per furnace unit. From all cold scrap on a continuous working week 1100 tons per furnace compared with 1500 tons per furnace using hot metal.

2. The increased production reduces the overall cost per ton of steel by spreading fixed expenses over a higher tonnage.

3. The following variable costs also show substantial savings: (*a*) electricity; (*b*) electrodes; (*c*) furnace refractories; (*d*) oxygen used in arc furnace; (*e*) fettling materials.

4. The above financial savings more than offset the cost of operating the pre-refining unit.

A summary of phosphorus levels taken over a long period shows that: 50% of all heats made are below 0·02%P, 41% are between 0·02% and 0·03%, giving a total of 91% below 0·03%. The remaining 9% were below 0·05%, 7·8% being below 0·04%P.

The new electric melting shop, operating with oxygen/pre-refined blast-furnace metal in a wide range of composition, represents the latest of a series of technical innovations which have been a feature of Brymbo's history. The present developments stem essentially from 1950 when Brymbo was the first British steelworks to make use of the technique of desiliconizing blast-furnace metal in the ladle with the oxygen lance. The new Brymbo process is the logical development of this technique and now makes it possible for the arc furnace to use large quantities of molten metal offering greater flexibility and higher availability than ever before as compared with conventional open hearths producing similar qualities. Refractory costs have also been greatly reduced.

The process has aroused considerable interest abroad and there is no doubt that the electric arc furnace will, in future, play an even greater part in steel production. There is, however, no reason to think that this system of pre-refining must necessarily be confined to electrical steel plants as OH operators could enjoy the same advantages and have hot metal of suitable and regular composition for their process at an economical cost.

ACKNOWLEDGMENTS

The author wishes to record his thanks to the directors of the GKN Steel Company Ltd for their permission to publish this paper and to Mr H. W. A. Waring, C.M.G., for his counsel and encouragement in this development.

Thanks are also due to the engineering and technical staff at Brymbo for their valuable assistance in overcoming the many difficulties experienced during the early development period, also the melting shop personnel for their splendid co-operation. Progress is continuing on this process and the steady improvements are recorded.

Application of flow research to industrial furnaces with particular emphasis on soaking pits

Herbert Boenecke, Dipl.-phys.

SYNOPSIS

The development of modern furnace building is being increasingly influenced by scientific knowledge relating to heat transfer within the furnace and the heating of the charge.

Wherever industrial furnaces are fired with solid, liquid, or gaseous fuels, and waste gases arise, it is necessary when building the furnace to consider the flow phenomena. Installations for the supply of fuel and air, together with the removal of the waste gases, are in the field of fluid mechanics. Apart from these problems of material transfer there are also the complicated mixing processes during combustion. The heat produced in the furnace has to be transferred to the charge by convection and radiation, and in various cases an evenness of temperature inside larger furnaces has to be achieved by forced circulation. Flow phenomena also play a role, which should not be underestimated, in electric furnaces if a special atmosphere, e.g. protective gas, is to be present.

The furnace builder must therefore become familiar with and utilize the basic elements of fluid dynamics. In this paper a review of the essential elements of fluid dynamics will be given, and some examples of applications of flow phenomena in the industrial furnace will be considered. 1901

INTRODUCTION

IN EARLIER DECADES furnace building depended on the experience of individual men who had often had only a practical training. Later, these were superseded by engineers with some theoretical training. Even then, however, their basic knowledge depended on self-acquired experience, i.e. the whole development of furnace building was empirical. In contrast, over the last few years, heating and flow phenomena have been studied on a scientific basis, so that today the functional relationship of the individual influencing factors is generally known.

In this connexion, it was recognized that flow phenomena were among the factors which played a decisive part in heat transfer in industrial furnaces. For this reason several studies were begun to consider whether and how the normal research methods used in aerodynamics could be applied to the industrial furnace.

One often hears the argument: 'Flow is not so important; radiation is the decisive factor in heat transfer'. In many cases radiation does indeed play the major part in effecting the transfer of heat in a heated furnace chamber, but from experience that, too, is influenced by the flow of the furnace gases. One is forced to the realization that the flow phenomena in the entire furnace chamber and during the whole of the heating period are of great significance for the transfer of the heat. Thus it is, for example, that as stable as possible a circulation of the furnace gases is striven after in the soaking pit so as to keep the temperature conditions as even as possible. The waste gas swirl should, wherever possible, fill the whole furnace chamber evenly and should circulate as often as possible; in this way a great turbulence should even out the temperature peaks arising in the combustion process.

In installing the burners in modern furnaces the main requirement is to achieve a rapid and intensive mixing of the fuels with as few burners as possible, using the most favourable burner injection speed. Whether short or long flame combustion is to be chosen depends on the size and shape of the furnace chamber. Thus zone lengths up to 8 m can be filled with a stable vortex from parallel jet burners, but also small zones from 2–3 m long can be heated quickly and evenly.

Numerous papers (*see* Bibliography) show that attempts are being made to study the basic elements of fluid mechanics, e.g. the law of continuity, dynamic pressure, Bernouilli's equation, energy and impulse law, as well as Reynolds Number (R), and to use them according to their significance in any problem that may arise. Nothing more, therefore, will be said of these basic elements in the following paper, which aims rather at giving by means of some practical examples an insight into the work done by a research centre for industrial furnace construction.

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1 *View of the flow laboratory*

THE MODEL TRIAL

In model trials on flow phenomena in the higher temperature ranges, it is absolutely necessary to apply the laws of similarity. In particular, the following two must be used: (*a*) geometrical similarity, and (*b*) condition of similarity according to Reynolds.

The first condition states that the dimensions of the furnace chamber, the burner, and the stock to be heated in the model must be geometrically similar to those in the full-scale example of the furnace. R must be related to a typical position in the furnace or model. In these conditions the flow phenomena in the model are mechanically similar to those in the full-size furnace, so that the results determined on the model can be transposed to fit the full-size furnace without further adjustment.

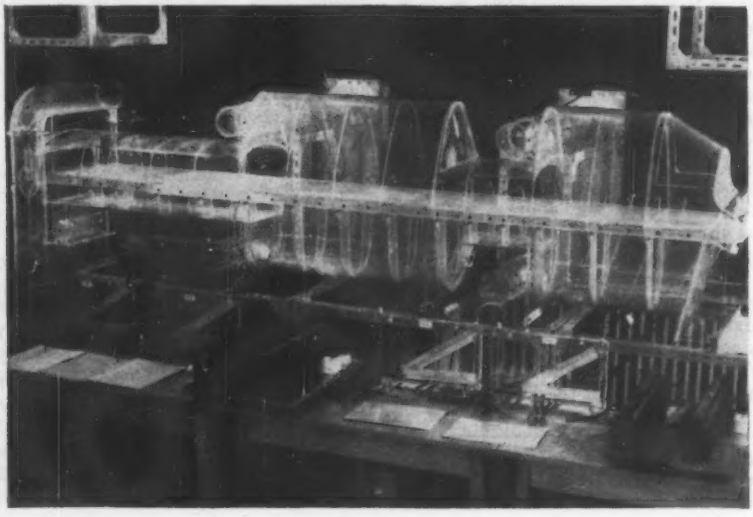
As the flow phenomena in industrial furnaces are determined in large measure by the mounting and the form of its burners, and the shape of the furnace chamber, it is worth while even in the planning stage to collect data on the most suitable shape for the furnace when built. For this reason, development work was begun several years ago in the field of heat and flow phenomena in the industrial furnace. Since then numerous small-scale and full-scale trials have been undertaken, which give a significant insight into what happens inside furnaces of different types of construction. In particular, it was possible in these trials both to observe very satisfactorily and also to photograph the flow in model furnaces. Finally, a series of quantitative as well as qualitative measurements was undertaken and compared with theory as well as operational trials.

Figure 1 shows a part of the flow laboratory with some models, by means of which the flow paths of furnace gases can be observed. The models, built of Perspex, are assembled in the same way as building blocks, so that alterations in the dimensions and shape of any design of furnace are possible. The scale of the models lies between 1:5 and 1:20 and is chosen according to R, in such a way that the proposed trial programme can be carried out with the existing equipment. According to requirements, the flow media used are sucked away by one of three fans with differing capacity, built under the flow.

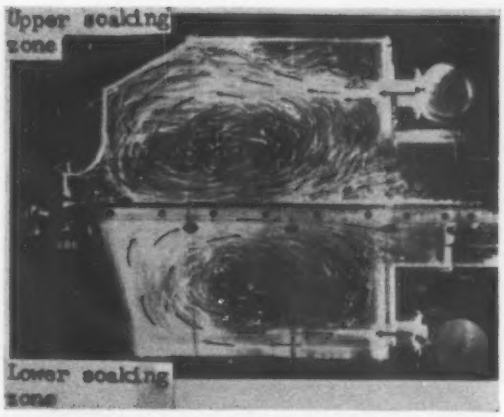
In Fig.1, for example, a model of a 3-zone pusher-type furnace with top and bottom heating, and standardized in its individual parts can be seen on the left. The length of the model is about 2·5 m with a breadth of about 0·3 m. The burner in each zone has an inflow duct with a measuring nozzle for the air volume, which is supplied from an electrically direct-controlled fan. In this way any desired zone admission can be achieved. The course of the static pressure can be measured on numerous places in the model to an exactness of 0·01 mm wg by means of high degree accuracy equipment (mm wg=kg/m²=0·2048 lb/ft²).

In addition, on the right in Fig.1 there is a model of a chamber furnace which is geometrically similar to a bogie hearth furnace. The second similarity condition for the transposing of the results acquired from the model to the full-scale furnace, i.e. the same R, was observed. In both cases R of about 27000 was used.

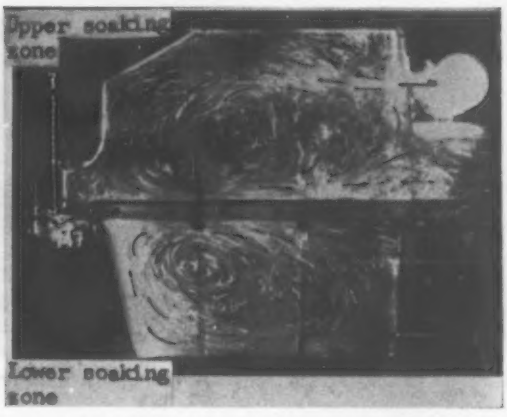
Figure 2 shows a model of a modern two-zone continuous pusher furnace. This form of construction is characterized by the symmetrical sub-division of the zones for top and bottom heating, the small number of burners, and the reversal of the flame in the burn-out area. The model shown here was built as a 1:8·5 scale model of an existing plant. In the



2 *Model of a 2-zone pusher-type furnace with top and bottom heating*



3a *Soaking zone flow pattern in a 2-zone pusher-type furnace with a large dia. burner*



3b *Soaking zone flow pattern in a 2-zone pusher-type furnace with a small dia. burner*

upper and lower soaking and heating zone there is an inflow nozzle as model-burner, whose cross-section can be varied by nozzle inserts. Both upper and lower zones have the same outlet. There are also numerous measuring points in this model in order to follow the course of the static pressure. The influence of the pusher- and drawing-doors on the flow phenomena can also be investigated in order to measure the volume of air drawn in or expelled through the opened doors.

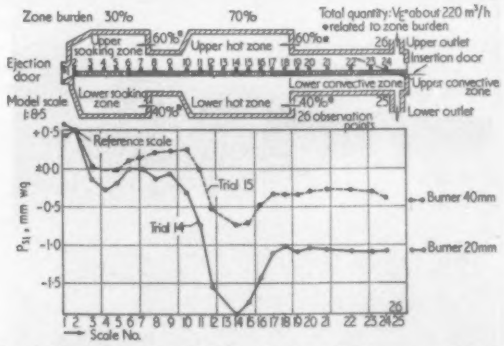
Individual flow phenomena can be qualitatively grasped very well. Thus Fig.3*a* shows the flow pattern, using a large dia. nozzle in the upper and lower soaking zone, as a regular elliptical eddy throughout the length of the zone, and this can also be seen across the breadth of the whole zone. In order to show the course more clearly, extra directional arrows have been added. By measurement it has been shown that the air in the model chamber circulates several times. According to the law of continuity, only the air volume introduced through the model burner flows away through the burner bridgewall of the model.

Figure 3*b* shows the flow conditions in the soaking zone with the same flow throughput but with a small nozzle diameter. An eddy is formed here also, but it is not distributed so evenly over the stock to be heated. In the upper furnace, which has a slightly greater volume than the lower furnace, an almost circular eddy has arisen. An area of turbulent outflow is shown towards the outlet side. In the lower furnace the elliptical eddy has remained somewhat more definite, although it is distorted towards the mouth of the nozzle.

Apart from the qualitative comprehension of flow phenomena, quantitative measurements of pressure can also be undertaken. As a selection from numerous data two series of measurements are compared in Fig.4, providing an insight into the flow phenomena in the furnace chamber. The air volume supplied remained unchanged in all four zones of the model. However, the diameter of the injection nozzle was altered from 40 mm in the first trial to 20 mm in the second trial. Both trials were carried out according to full-scale practice with R of about 60000. The datum measuring point lies above the tilting angle of the discharge door. As the outlet impulse at the nozzle is a result of the product of the secondary mass and the velocity of the air volume, this is greater using an injection nozzle with a small cross-section than one with a large cross-section. In this way the differing trends of both curves can also be explained. The following comparison of the highest pressure difference is significant:

Trial series	1	2
Nozzle diameter, mm	40	20
After calculation, mm wg	1·67	2·92
After measurement on the model, mm wg	1·25	2·41

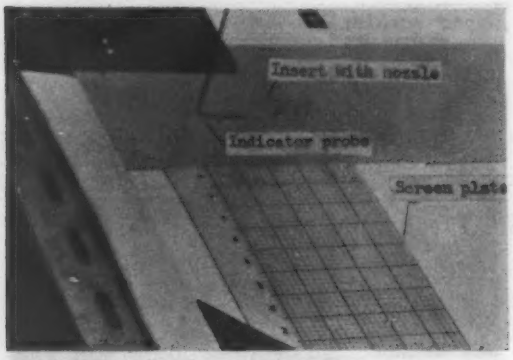
The measurements agree fairly closely with the theory, when it is considered that the pressure losses due to friction on the furnace walls were not taken into account in the calculation. If the influence of the temperature is also allowed for in the calculation, then the trend of the pressure in the furnace can be calculated satisfactorily in advance.



4 *Static pressure trend in the chamber of a 2-zone pusher-type furnace*

TRIALS ON FREE JET

For the investigation of flow phenomena the water model offers a simple but good aid. With this apparatus, investigation on the free jet can be undertaken, to study in detail the mixing processes at the mouth of the nozzle and in the neighbourhood of the jet; and this acquired knowledge can be applied to the construction of burners and of the burner stone.

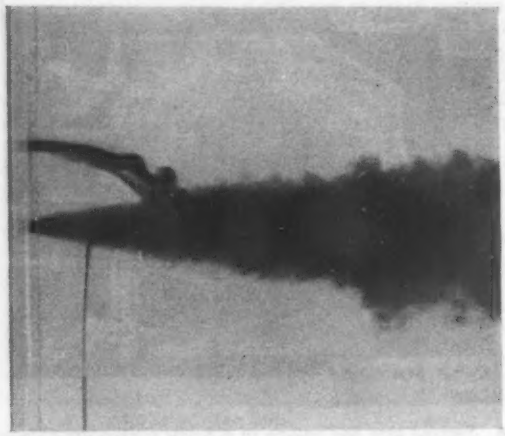


5 *Model wall built into the water channel for the investigation of free flows*

Two-dimensional flow phenomena in the water model can be made visible by the use of lycopodium powder, aluminium flakes, or plastic splinters. In three-dimensional investigations, the use of colour probes is best, since by using different colours the mixing processes and the special influence zones can be clearly shown. Some colour photographs of such three-dimensional flow phenomena as are discussed in the paper are shown here in black and white.

Figure 5 is a view of such a water model and shows, from above, the free measuring stretch with the built-in model wall. The exit speed of a free jet was altered in a simple way, by raising or lowering a level vessel as container for the jet fluid. The sinking of the fluid level in the vessel between two calibrating marks was the measure for the outflow volume.

In the middle of the model wall an exchangeable conical insert is placed, with the form of nozzle to be investigated, and from this issues the coloured water jet. To make the influence of the trial jet on its surroundings visible, a small indicator probe, with a diameter of 0·3 mm and easily movable, is introduced into the water basin; through this probe some contrasting fluid flows out with as small an exit speed as possible. In the trials, especially with turbulent jets, a screen-plate with which the expansion of the jet can be photogrammetrically measured is inserted under the free jet.



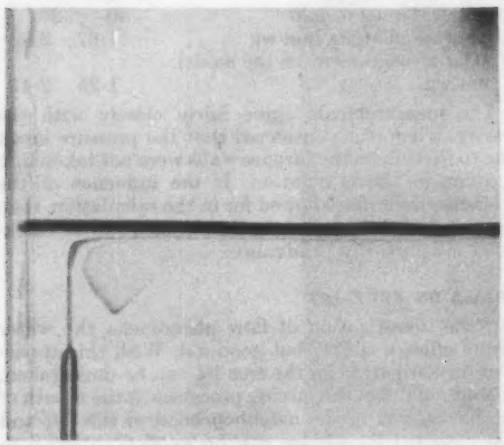
7 *Two free flows of differing exit speeds*

With this arrangement, the formation of a jet can be observed in all its details; the influence of several jets on each other can also be examined.

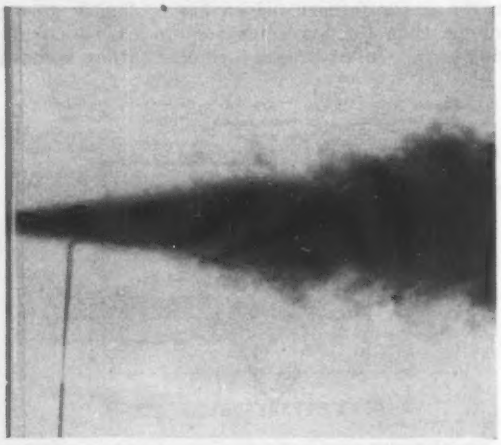
The particular case of the laminar free jet (R=600), which does not occur in industrial furnaces, is shown in Fig.6*a*. The issuing jet does not mix for a relatively long stretch with the jet thread of the indicator probe that has been brought into immediate contact with it. The opposite is shown in Fig.6*b*. Under otherwise similar conditions, the exit speed is about eight times greater than with the laminar stream (R about 5000). After the exit a turbulent jet is formed, which mixes intensively with the surroundings, the contrasting fluid.

As the burner jets are built up mostly from several media, an awareness of the influence of free jets on each other is especially important. If two jets with different exit speeds mix with each other, then the jet with the higher impulse sucks into it the neighbouring lower impulse jet, absorbing it completely. Figure 7 shows how the jet which has been sucked up has about half the exit speed of the jet which absorbed it.

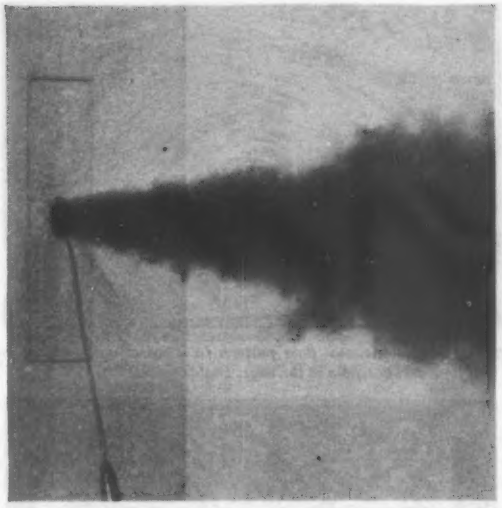
Apart from the formation of the flow, a knowledge of the processes in the neighbourhood of a funnel-shaped nozzle mouth, which are due to the shape of the burner stone, is important.



6a *Laminar free flow in the water channel*



6b *Turbulent free flow in the water channel*



8 *Turbulent free flow from widened trumpet-shaped nozzle mouth*

Figure 8 shows the behaviour of the area round the stream with a funnel-shaped nozzle mouth. The coloured thread from the indicator probe is here sucked right into the mouth of the nozzle. As the diffuser has a relatively wide angle of opening to the stream axis (30°) the stream begins to dissolve even in the diffuser. Thereby an area of partial vacuum arises which causes this suction.

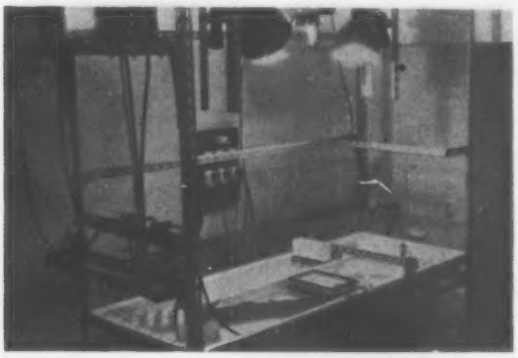
Such flow experiments in a water model can be transposed to an air channel without difficulty. This is shown in Fig.9, where the model trial is reproduced with a turbulent air-stream using a 25-mm nozzle dia. With similar test conditions, there is practically no difference *vis-à-vis* the water model trial.

MODEL TRIALS ON THE SOAKING PIT

The water model is not merely suitable only for the investigation of specific individual problems in the industrial furnace, but also for flow model trials in enclosed furnace chambers. A series of preliminary tests on flow phenomena in the soaking pit was therefore first of all undertaken in a water channel, to obtain accurate data on constructional details, e.g. the arrangements of burners and offtakes, the required height of the free furnace chamber above the charge, etc. without having to use expensive perspex models in the air model.

Figure 10 shows a test rig suitable for such investigations. The free water stretch is almost 3 m long and 0·6 m wide. In the middle of the measuring stretch

9 *Turbulent free flow in air channel*



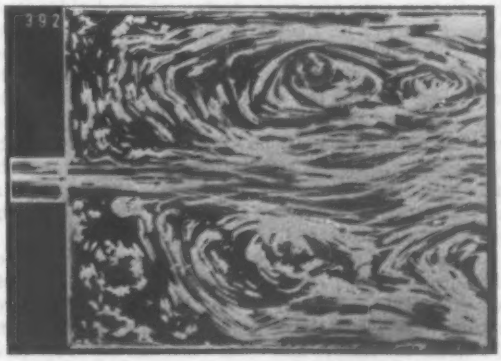
10 *Water channel with built-in model and measuring equipment*

there is a small chamber with a removable perspex cover. Without the cover in place, two-dimensional flow phenomena play on the surface of the water, i.e. in the horizontal plane, and correspond to the processes in the vertical plane through the burner in full-scale practice.

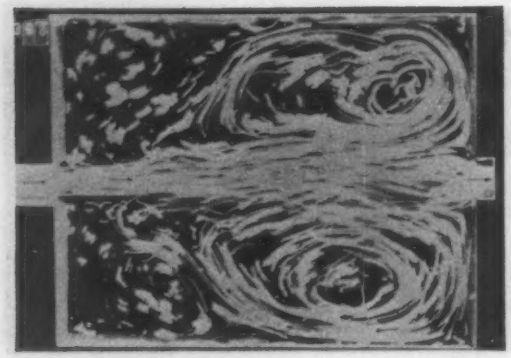
The most common case of the effect of an impulse in combination with pressure strength occurs when media are flowing through a sudden cross-sectional change in the direction of the flow. This occurrence of a sudden expansion is the basis for research into the trend of pressure in elongated furnace chambers.

Figure 11 shows in two-dimensional representation the qualitative flow pattern. In a model with a breadth equal to eight times the nozzle dia. a stream of water flows in centrally and can flow out on the side opposite the inlet over the complete width of the model, whereby a reverse vortex is formed towards both sides. By means of aluminium flakes scattered on the surface of the water, the flow path and the outflow of the individual flake particles are made visible. The processes can be better judged if the movement of the aluminium particles can be photographed at the same time.

When a wall with an outlet almost the same size as the inlet cross-section is placed behind the reverse vortices (Fig.12*a*), then both reverse vortices remain and the core of the stream whose build-up point lies in the opposite outflow opening flows directly away, while the flow space, which, because of the back wall, has been transformed into a chamber, is filled by the two vortices. Similar flow patterns, but with an



11 *Two-dimensional flow pattern of a free flow with sudden expansion*



12a *Two-dimensional flow pattern in a vessel with central in- and out-flow*

12b *Two-dimensional flow pattern in a vessel with central inflow and out-flow at the edge. Unstable vortices before turning over*

12c *Two-dimensional flow pattern in a vessel with central inflow and out-flow at the edge. Stable vortex*

12d *Two-dimensional flow pattern in a vessel with central inflow and out-flow at the edge. Unstable vortices after turning over*

asymmetrical reverse vortex directed more towards the centre of the chamber, result from the movement of the offtake along the edge of the water model. The flow patterns are identical whether the offtake is above or below. Figure 12*b* shows the flow pattern in a chamber with an offtake sited below. The vortex is unstable and tends to turn over.

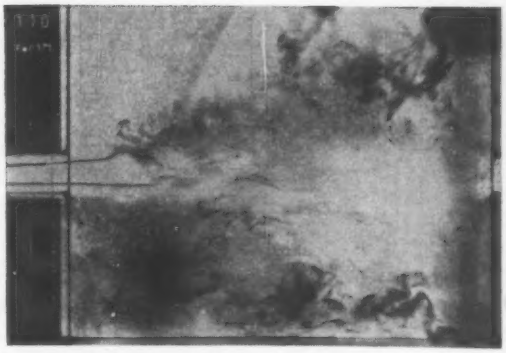
The further tests rely on full-scale soaking pit practice with the exit port set low, while the inlet port is moved into different positions between the middle and the edge of the water model. A completely stable circulation with one main vortex which divides itself almost equally into small corner-vortices throughout the entire chamber, and which shows the ideal flow-pattern, was achieved in the extreme case with the inlet port right at the edge, which corresponds to the top corner of the soaking pit chamber. For thermal and structural reasons, however, a burner cannot be inserted immediately under the cover. As long as the inlet port remains up to three times the nozzle dia. away from the edge, then the stable condition of the vortex roll is preserved.

These trials are significant for the arrangement of the burner in the furnace chamber. A series of tests has definitely established that the main vortex remains stable when the distance from the cover is 1·8 to 2·0 times the nozzle dia. even when the input speed is low (Fig.12*c*). If the distance from the inlet port to the top of the furnace is more than three times the nozzle dia., then an unstable condition sets in, whereby the direction of flow can be reversed (Fig.12*d*).

The same phenomena can be seen three-dimensionally (Fig.13*a–c*). The chamber corresponding to the soaking pit is made by inserting the perspex covers horizontally under the water. The different contrasting fluids are supplied through colour probes built into the roof and the floor.

In further trials the outlet port, in accordance with full-scale soaking pit practice, is placed under the inlet port. Apart from this, the inlet port is asymmetrically rounded in order to speed up the circulation process in the chamber. As in Fig.14*a*, the vortex is preserved completely intact; however, because of the asymmetrical shape of the nozzle mouth, the vortex takes on an elliptical shape compared with the circular shape with sharp-edged parallel outflow. Similarly in a chamber containing ingots or slabs the rotation of the vortex roll between the rows of ingots is preserved (Fig.14*b*). This fact is of decisive importance for the correct sizing of a soaker chamber and for regular pit practice.

To confirm the influence of the burner dia. on the flow process, the entry cross-section of the nozzle was varied in the distance of twice the nozzle dia. Reducing the original cross-section by a half or a quarter produced virtually no alteration of the flow pattern in the two-dimensional trial. On the other hand, considerable differences were to be observed in the three-dimensional trial (with colour probes). With a large cross-sectional entry the mixing process extended on a wide



13a *Three-dimensional flow pattern in a model chamber with central in- and out-flow*

13b *Three-dimensional flow pattern in a model chamber with central in-flow and out-flow at the edge. Unstable vortices after turning over*

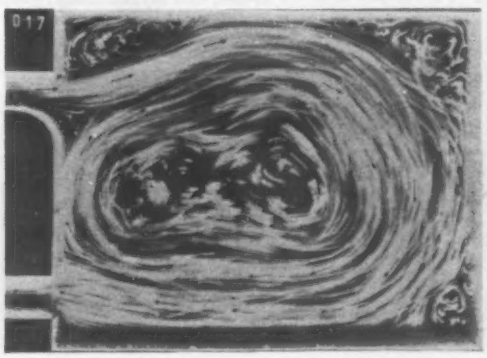
front over the model chamber, while with an especially small cross-sectional entry (i.e. with a high speed of entry) the mixing process spread over a narrow edge zone along the chamber walls, although even in this area with correspondingly greater speed.

Such investigations in the water model certainly provide a valuable insight into flow phenomena; however, for quantitative results the velocity distribution has to be obtained by a photographic method. A small amount of aluminium flake is strewn into the flow path in order to photograph the free movement of individual particles in a specific time, namely the time required for the exposure. Figure 15*a* shows such a photograph. The flow pattern is subdivided into four areas by the superimposed crossing of the axes where the zero coordinates are approximately in the centre of the vortex roll. The velocity distribution in these four areas is to be determined. The local speed of the particles whose path cuts the axes' crossing point can be determined by measurement of the free movement and with the help of the exposure time, and entered in the appropriate section of the axis. Figure 15*b* shows a trial photograph evaluated by the method described. Accordingly, an estimate of the circulation volume is possible with sufficient accuracy. Velocity distribution and direction of flow can be of particular significance in specific cases.

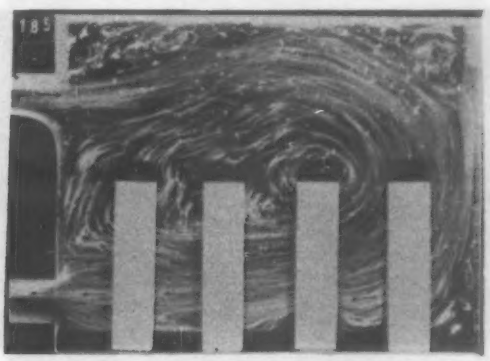
Just as the trials on the free jet can be carried out in water and air, so the described trials in the water model can be undertaken in an air model. Figure 16

13c *Three-dimensional flow pattern in a model chamber with in-flow and out-flow at the edge. Stable vortex*

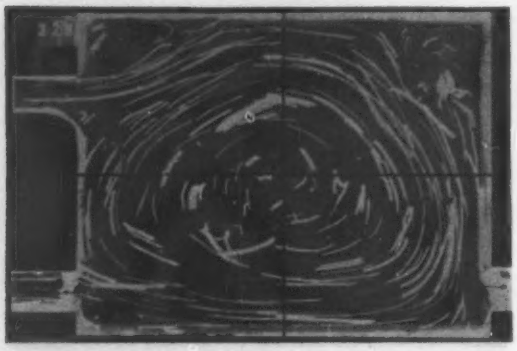
shows such a test rig with a perspex soaking pit model to a scale of 1:10 of an actual installation, and with the equipment for direct measurement of the velocity distribution using pitot probes. The volume of air supplied and withdrawn in place of heating gas, combustion air, and waste gas is measured according to the through-flow principle. Qualitative flow investigations were undertaken with atmospheric air at room temperature. With the help of electrically controlled fans both the individual volumes and the total volume



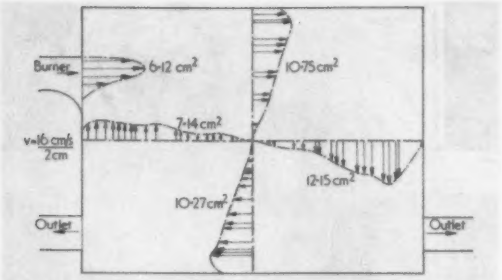
14a *Two-dimensional flow pattern in a flow area similar to the one-way soaking pit without charge*



14b *Two-dimensional flow pattern in a flow area similar to the one-way soaking pit with charge*



15a *Test photograph for determining the velocity distribution in a flow area similar to a one-way soaking pit*



15b *Result of the evaluation of a test photograph for determining the velocity distribution*

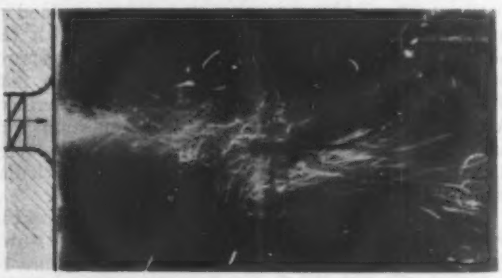
could be varied. The flow is made visible by formaldehyde gasified immediately before the input nozzle. Because of the lowering of the temperature on being sucked out, the formaldehyde is sublimated into small flakes.

With three-dimensional observation it is necessary to determine step by step the flow phenomena in vertical and horizontal light-sections laid through the furnace chamber. For the model test it was necessary to choose the same R (according to the formula $R=v\times d/\nu$) as in the flow phenomena in the full-size furnace chamber, so as to be able to translate the acquired result into practice. Accordingly in the model experiments R of 60000 at full admission was used. With reduced volume, i.e. half load or 20% load, R is 30000 or 12000 and still lies considerably above the critical R of 2300. Laminar flow is not to be expected between ingots in the furnace chamber, owing to the turbulence at the exit of the jet from the model burner, and the very extensive mixing with the circulating volume already in the model. Even with numbers lower than those given above, a translation of the model test results can be applied to the full-scale installation without serious limitations.

The flow conditions in the furnace chamber, as emerges from the experiments, can be influenced by the structural arrangement of the supply lines to the burner and by the form of the burner stone. Figure 17*a* shows the flow pattern of a jet issuing from a trumpet-shaped nozzle with a built-in diffuser. The centrifugal jet dissolves. Translated into terms of the combustion process, a flickering turbulent flame is formed. If the mouth of the nozzle is simply enlarged slightly downwards, as shown in Fig.17*b*, then the agglommerated flame frees itself from the mouth of the nozzle and forms on the rounded side a strong vortex whose axis lies at an oblique angle to the direction of flow.

The behaviour of the jet from the burner is decisively influenced by the arrangement of the supply leads in front of the burner. If the supply line and the burner lie along the same axis, then the symmetry of the flow is not disturbed on leaving the nozzle. It is often found in practice that there is an angle of up to 90° in the supply line before the burner. In this case a tilting of the jet is to be expected unless there is enough room for this disturbance in the flow to be evened out.

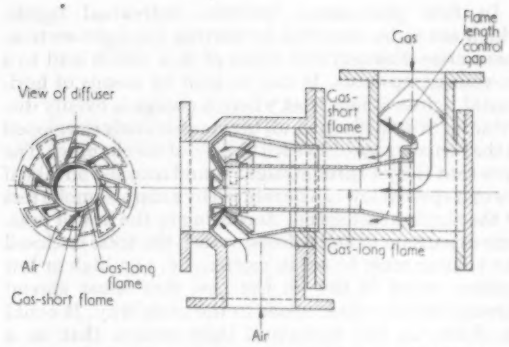
On the basis of this knowledge a burner has been developed in which these influences are insignificant. Figure 18 illustrates a section taken through one such



17a *Parallel flow in the air channel with symmetrically rounded nozzle mouth and built-in diffuser. Nozzle 50 mm dia.*

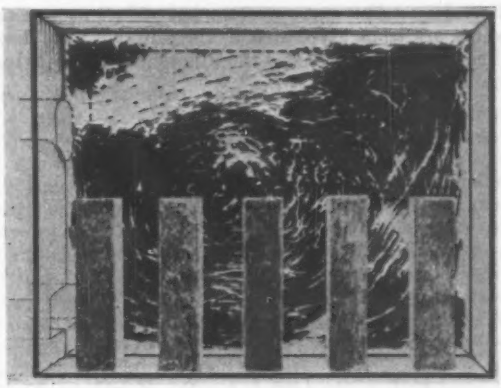
16 *Model of a one-way soaking pit with measuring equipment for velocity distribution*

17b *Parallel flow in the air channel with symmetrically rounded nozzle mouth and built-in diffuser*

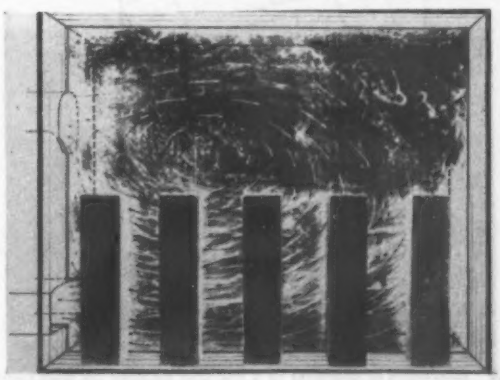


18 *Vortex flow burner with diffuser for short and long flame*

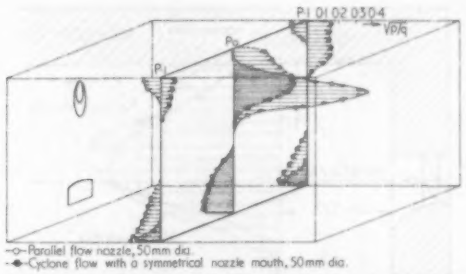
cyclone burner, and a view of the diffuser from the front. When the movable valve is in such a position that the gas in the casing tube reaches the mouth of the burner tangentially, then because of the twisting device an intensive mixing takes place, consequently producing a short burning flame. The disturbances otherwise arising for gas and air owing to the asymmetrical flow from the supply lines are thereby largely avoided. When the valve is in the opposite position, the gas in the central tube streams to the mouth of the burner, and owing to the less intensive mixing with



19a *Flow pattern in the model of a one-way soaking pit with charge. Vortex flow burner with long flame*



19b *Flow pattern in the model of a one-way soaking pit with charge. Vortex flow burner with short flame*

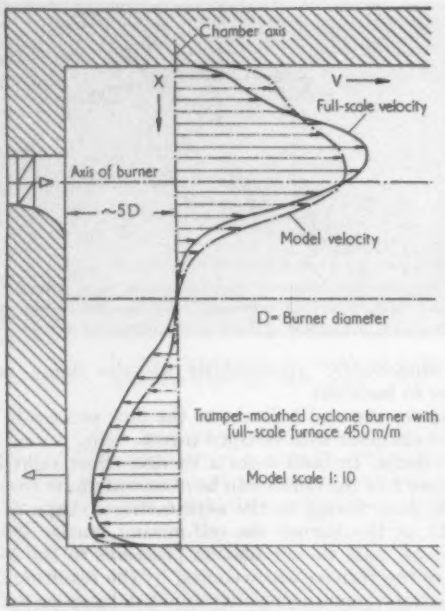


20 *Comparison of velocity distribution between parallel flow and vortex flow with asymmetrically rounded burner mouth in the middle section of a one-way soaking pit model*

the tangentially approaching air the flame takes longer to burn out.

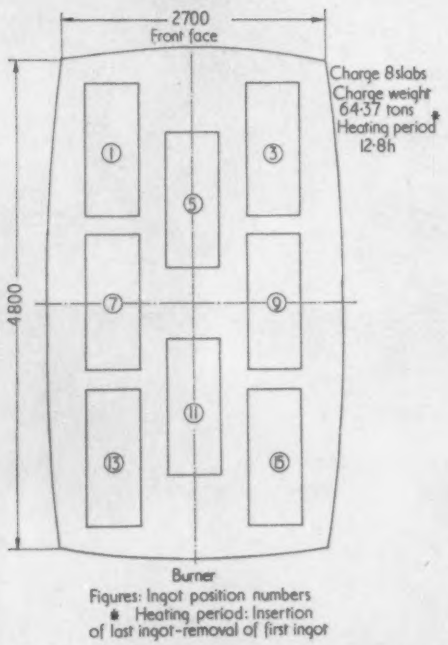
Figures 19*a* and *b* illustrate the flow process in the model chamber with charged ingots, using a long and short flame. In both cases a suction effect right into the mouth of the nozzle can be observed under the exit of the flow. Owing to the asymmetrical shape of the mouth of the burner the self-mixing burner stream dissolves, and the circulation processes in the lower part of the furnace are favoured by the resulting area of partial vacuum. Contrary to what happens with a long vortex jet, the damming point with a short stream formation moves from the lower to the upper furnace. The turbulence roll fills only about two-thirds of the chamber in this process, as the axis of rotation is closer to the side from which the jet emerges. The space outside the roll, i.e. on the side opposite the

21 *Smoke test in a one-way soaking pit*



22 *Velocity distribution comparison between a model and full-scale operation on a one-way soaking pit*

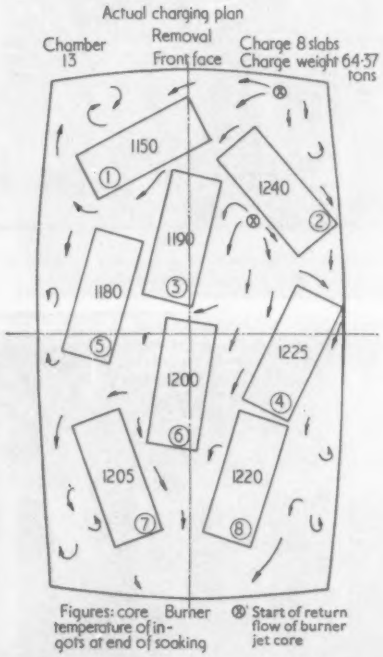
burner, is filled by a turbulent mixing zone which is relatively limited in area. In tests comparing full load with part load the flow pattern scarcely changes, although the local velocity changes in relationship to the exit speed at the mouth of the nozzle.



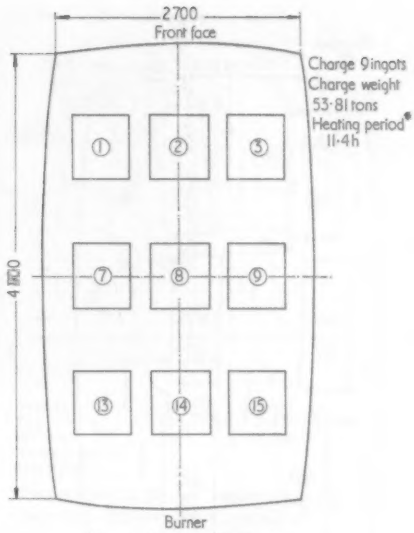
23a *Charging plan for a one-way soaking pit with eight slabs*

In flow phenomena between individual ingots, which are to be observed by moving the light-section, there arise disintegrated areas of flow which lead to a movement upwards. It can be seen by means of horizontal light-sections that where a charge is evenly distributed over the hearth, all ingots are evenly enveloped in the furnace gases down to the floor of the chamber. The view that the jet turns straight round into the offtake if the exit speed is low can be refuted by a simple smoke test at the slowest exit speed. According to the law of pressure expansion in an enclosed vessel, the total enclosed gas volume must be set in motion, i.e. at a high or low outflow speed of the jet the new flow must spread throughout the whole space in the same way. It could be shown in the horizontal light-section that as a result of the asymmetrically built burner in the upper furnace a flow prevails under the roof which is similar to that in the two-way furnace. Two main vortices are thereby formed with vertical axes, in contrast to the big main vortex with the horizontal axis below the axis of the burner.

As with trials in the water model, tests in the air channel can also be evaluated quantitatively. The results of two series of measurements with probes are tabulated in Fig.20. The measurement of the velocity distribution of a simple parallel jet without a twisting nozzle is compared with that of the vortex flow with asymmetrical nozzle. Both investigations were undertaken with full volume admission. The differences in the velocity distribution at the individual measuring points are to be attributed to the different formation of the model burners and the differences in supplying the flow medium.

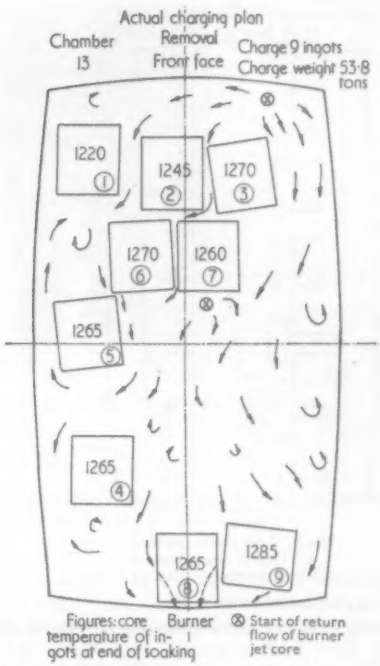


23b *Execution of charging in a one-way soaking pit with eight slabs. (Photogrammetrically evaluated.) Very badly distributed charge*



Soaking pit dimensions are in mm

24a *Charging plan for a one-way soaking pit with nine ingots*



24b *Execution of charging in a one-way soaking pit with nine ingots. (Photogrammetrically evaluated.) Very badly distributed charge*

OPERATIONAL TRIALS IN A ONE-WAY FURNACE

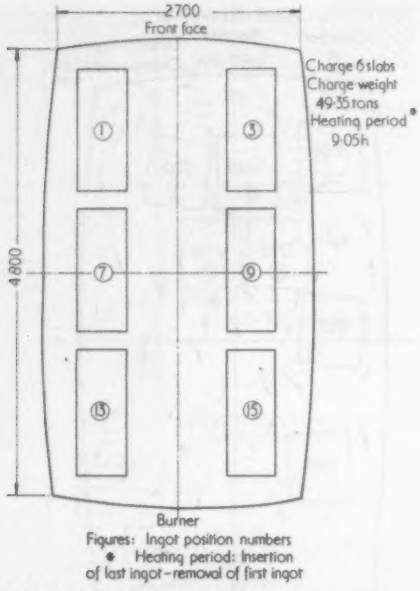
To test the application of the results from the model trials in full-scale operating conditions, investigations were also undertaken in a full-size furnace. First the flow path was examined in the cold condition of a furnace with 12 charged ingots and the measurement of the velocity distribution at various points in the furnace was made by a special probe. In order to make flow visible and capable of being photographed, smoke powder was burnt at various points in the furnace chamber. Two air fans for the supply of the burner with gas and air, and the suction gear were in operation. Figure 21, looking towards the burner wall, shows qualitatively the flow in the furnace chamber under the mouth of the burner. The suction into the asymmetrically rounded mouth of the burner is clearly visible.

With quantitative measurements the flow phenomena must not be disturbed. This was achieved by placing a cabin for men and measuring equipment, the size of two ingots, into the furnace chamber. The pressure differential probe was led inside the enclosed furnace chamber by a pipe between the roof and the floor in such a way that it could be brought to any point in the chamber. The flow direction was determined at every measuring point by a thread probe. The results of these measurements accorded satisfactorily with the model tests.

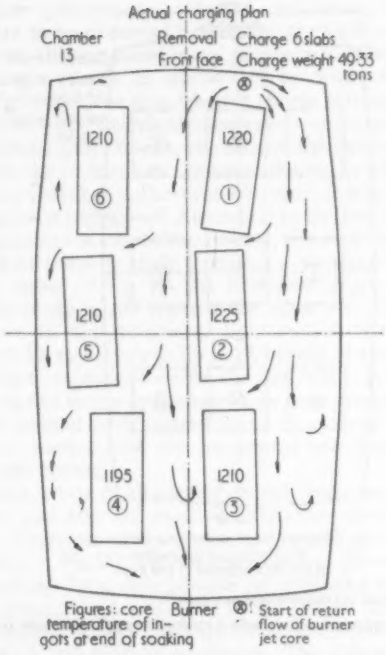
25 *Two-dimensional flow pattern in a one-way soaking pit model in the water channel with badly distributed charge*

In conjunction with these cold measurements, trials on a heated furnace were undertaken. With a special water-cooled probe, which was let in through the furnace roof, the differential pressure was measured at various points at various depths, with a furnace chamber temperature of about 1300°C. In Fig.22 the velocity distribution in the model chamber is compared with the full-scale furnace velocity which was measured in the vertical plane through the axis of the burner at a distance of five times the distance away from the mouth of the burner. The agreement of the results is satisfactory if it is remembered that the model is absolutely airtight while the full-scale furnace, despite the most careful construction, does show leakages, especially at the sand pockets.

It has been discovered from such investigations that the furnace gas volume to be circulated can be influenced by the pre-pressure of gas and air at the burner, without having to change the pressure in the furnace chamber. This is a distinct advantage in furnaces with a metallic air recuperator as opposed to furnaces with a ceramic recuperator. As metallic recuperators are virtually airtight, there is no obstacle to raising the burner pre-pressure. In contrast, this is not possible with ceramic recuperators as the air pressure at the



26a *Charging plan for a one-way soaking pit with six slabs*



26b *Execution of charging in a one-way soaking pit with six slabs. (Photogrammetrically evaluated.) Well distributed charge*

burner can bear only little mm wg, owing to the need to keep the air infiltration to a minimum, and can scarcely be altered. A further advantage in altering the burner pre-pressure is that the temperature differences that sometimes occur between the top and bottom of individual ingots can be evened out.

As a result of the experiments so far, it could be shown that the knowledge gained through model tests can in certain conditions be applied at once to full-scale soaking pit practice. In practice, however, the heating of a charge is extremely varied; in particular the soaking is more or less unsatisfactory from ingot to ingot, so that difficulties can arise in rolling the ingots. Within the framework of withdrawal and operating tests a considerable amount of useful data was collected on this matter from a number of charges, showing that the flow path of the furnace gas in the chamber is considerably influenced during the heating of the charge by the method of loading and arranging the individual ingots or slabs.

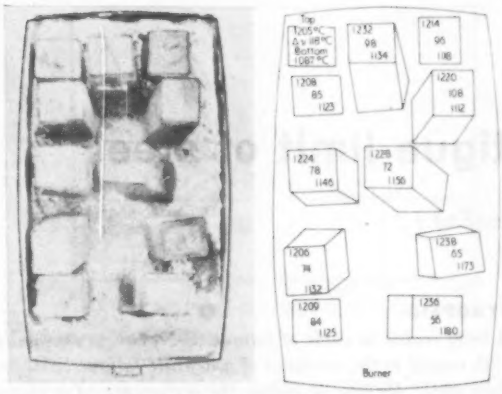
It is known that in practice ingots cannot always be placed as might be wished. Figure 23*a* represents, for example, a charging plan for eight slabs which is given to the crane-driver. The practical execution of this charging plan can be seen from Fig.23*b* which has been prepared by photogrammetric means. The positioning of the slabs differs considerably from what was desired. Corresponding temperature differences on the sectional areas of the rolled-out ingots at the shears are noted. They amount to as much as 100° between individual ingots according to the figures registered. Under normal circumstances charging is not done according to a plan given in advance. The charging plan (Fig.24*a*) was drawn up afterwards. The actual distribution is shown by Fig.24*b*. The temperatures noted again at the bloom shears indicate that ingots 1 and 2, owing to the unfavourable flow path, have not been heated to the same degree as the others which, standing almost free, allowed the heat to circulate better round them. From these two examples illustrated it is clear that the flow is considerably upset by an asymmetrical distribution of the ingots, and as a result the temperature distribution in the ingots is uneven.

These conditions occurring in practice have been copied in the water model (Fig.25). In this, one ingot was left out of the charging row. The result was that the main vortex was lowered and the axis from the longitudinal middle of the chamber was moved downwards and in the direction of the burner.

Figures 26*a* and *b* show the charge plan and the actual position of six slabs. With such an orderly charge the flow path of the furnace gases is hardly disturbed. It is to be expected, therefore, that the difference in temperature between the slabs will be smaller than in both the foregoing examples. The recorded temperatures confirm this: the greatest difference amounted to 30°.

These practical investigations have been improved as far as temperature measurement is concerned by measuring the temperature at the top and the bottom of the individual ingots after rolling. Thereby the effect of bad or good furnace charging on the flow path and, what is ultimately relevant here, the temperature in the ingots can be shown even better. With bad charging (Fig.27*a*) the average temperature difference between top and bottom is 85°, with good charging (Fig.27*b*), 47°.

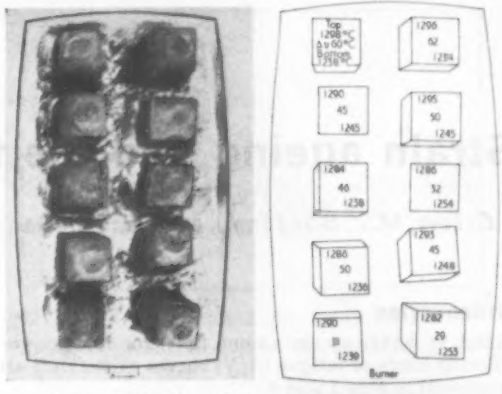
The results shown by operational trials give a valuable insight into the processes in the furnace and the difficulties which arise therein. It is essential that the ingots be arranged symmetrically in the chamber for



Average value, °C (trial 7)
Top 1220
Bottom 1135
Average temp. difference 85

Kopf top
Fuss bottom
Brenner burner

27a *Temperature difference between top and bottom of ingot where the ingots are badly placed*



Average value, °C (trial 5)
Top 1290
Bottom 1243
Average temp. difference 47

Kopf top
Fuss bottom
Brenner burner

27b *Temperature difference between ingot top and bottom where the ingots are well placed*

the charge to be evenly and well soaked. The higher, then, the circulation speed of the furnace gases is in the heating, the greater effect any asymmetries in the flow pattern have on the heating of the ingots. In this connexion, it is obvious that the furnace hearth must be maintained carefully and regularly in order to be able to place the ingots on any desired position on the hearth, and that the crane-driver must be instructed to charge the furnaces according to the given requirements without any loss of time.

SUMMARY

From investigations into free jets it has been shown that the results from flow trials on a model can be transposed into full-scale furnace practice. It is, however, advisable and useful to compare the model trials with operational trials, where the influencing factors can be investigated singly and in conjunction with each other. In this way it has been recognized that the method of charging a chamber, the flow of the furnace gases during the heating of the charge, and the temperature condition inside an ingot and from ingot to ingot of a charge at the end of the heating process, stand in very close relation to each other.

In a series of examples free jets were shown under differing conditions. In connexion with this, two-dimensional flow phenomena in the water model were described and translated into three-dimensional conditions in an enclosed container. By operational trials it could be confirmed that the soaking of the charge at the end of the heating process was insufficient if the flow were disturbed.

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Powder Metallurgy Joint Group

Meetings in 1961

The Powder Metallurgy Joint Group of The Iron and Steel Institute and The Institute of Metals announces that the following meetings will be held in 1961:

Discussion on '*The appraisal of powders for pressing and sintering*': I. Techniques for the evaluation of powders; II. The relationship between powders and their pressing and sintering behaviour, **Monday and Tuesday, 17 and 18 April,** at The Royal Commonwealth Society, Craven Street (near Northumberland Avenue), London W1.

Symposium on '*Sintered high-temperature oxidation-resistant materials*', **Thursday and Friday, 7 and 8 December,** at Church House, Great Smith Street, London SW1.

Offers of original papers for this symposium should be sent to The Secretary, Powder Metallurgy Joint Group, 17 Belgrave Square, London SW1, from whom particulars may also be obtained of the contents of the Group's half-yearly periodical *Powder Metallurgy*.

Strain ageing and the fatigue limit of steel

J. C. Levy, M.S., B.Sc.(Eng.), and S. L. Kanitkar, M.Sc.(Eng.)

SYNOPSIS

A brief review is made of fatigue (S/N) curves especially with regard to the existence of a definite fatigue limit for mild steel. By this is meant the occurrence of a sharp 'knee' in the curve at 2–4 million cycles beyond which it is impossible to obtain a fatigue failure.

Evidence is outlined for believing that the fatigue limit is due to the ability of mild steel to undergo strengthening by strain ageing. A model is described to illustrate how the knee could be formed if such strengthening occurs during a fatigue test.

In the main part of the experimental work it is shown that the knee can in fact be eliminated if the strain ageing ability of the steel is exhausted by prior 'coaxing' of the material from a stress level below the original fatigue limit. The S/N curve of the coaxed material is smooth with continual failures up to 100 million cycles.

It is also shown that the percentage by which the endurance limit can be raised by coaxing is about the same as the percentage by which the ultimate tensile stress can be raised by repeated strain ageing in an interrupted tensile test. 1862

INTRODUCTION

THERE IS GENERAL agreement that, for metals, two different kinds of fatigue (S/N) curves exist. They are illustrated in Figs.1 and 2.

To define a 'limiting stress' in fatigue, the terms 'endurance limit' and 'fatigue limit' have often been used synonymously but it is useful to distinguish between them as follows:

Endurance limit (Fig.1) should be used for those metals having S/N curves which do not become truly parallel to the N axis. This applies to copper, brass, nickel, magnesium, silver, gold, and most aluminium alloys. The endurance limit is defined as that stress amplitude required to cause fatigue failure in a stated number of cycles. In Fig.1, S_E is called the endurance limit based on N_E cycles.

Fatigue limit (Fig.2) is a term appropriate to those materials (chiefly low-carbon steels tested in a non-corrosive environment) which either fail in a few million cycles or never fail at all. It is the greatest stress amplitude a material can withstand for an infinite number of cycles. Only those S/N curves which show a knee definitely become parallel to the N axis as this definition requires.

At first sight the knee in the S/N curve of steel gives an impression that there may be a fundamental difference between the deformational behaviour above and below the fatigue limit. However, no such difference exists. The same processes appear to operate except that below the fatigue limit the material tends to reach a stable condition. This applies, for example, to changes in the X-ray pattern,[1] the slip band formation,[2] and the damping capacity.[3]

Strain ageing and the 'knee'

Besides being the only common metal to show a knee in its S/N curve, mild steel is the only one to show an upper yield point in its ordinary stress–strain curve. Consequently the suggestion has been made that these two phenomena may be related to one another.

The occurrence of an upper yield point is indicative of ability to strain age, a spontaneous strengthening which takes place after plastic deformation. In mild steel this is thought to be due to the action of carbon and nitrogen atoms in the iron lattice and it has in fact been found that removal of carbon and nitrogen tends both to suppress the upper yield point and to give a virtually smooth S/N curve.[4]

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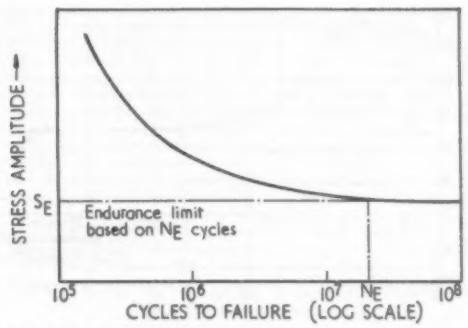
An explanation to show how the knee could be formed as a direct result of strengthening due to strain ageing has recently been advanced by one of us[5] and is depicted in Fig.3. The smooth curve A–A' is postulated to represent the S/N curve of the material were it, by some means, prevented from strain ageing. The other smooth curve X–X' would be obtained if the material were fully strain-aged before the commencement of the test. Both curves are smooth because no strain ageing is allowed to occur *during* the test.

In practice, strain ageing does occur since it is due to a diffusion process which inevitably follows the plastic deformation known to be associated with fatigue damage. There is a consequent raising of the strength and in Fig.3 the actual S/N curve will fall somewhere between A–A' and X–X', say along P_1P_2 at stresses S_1 and S_2. However, at a lower stress S_3 the conditions of stress, time, and temperature may be such that sufficient strain ageing has taken place to convert the material to that represented by X–X' before it can fracture at K. If S_3K does not intersect X–X', fracture cannot then occur and the observed S/N curve will be P_1P_2KR with a knee at K.

A model of this kind accounts for the fact that changes in the X-ray pattern, the slip pattern, and the damping capacity can be observed below the fatigue limit. In Fig.3 for example, slip would be expected at least in the shaded region of the diagram.



1 *S/N curve without a knee*

The fatigue of steels is a race between damage due to fragmentation of the crystals and strengthening due to strain ageing. The fatigue limit cannot be looked upon as a line of demarcation between different kinds of behaviour but rather as a critical stress at which strain ageing manifests itself most impressively in the S/N curve.

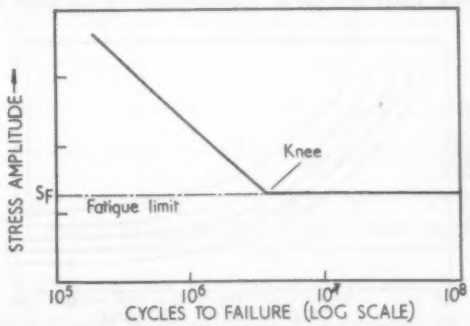
Tests at elevated temperatures[6] give results which are consistent with Fig.3. It is found that the knee moves to a higher stress and a smaller number of cycles, an effect which can be attributed to the more rapid strain ageing made possible by the increased rate of diffusion at higher temperatures.

However, neither this finding not the fact that the knee disappears on removal of carbon and nitrogen should be regarded as wholly positive confirmation of Fig.3. Raising the temperature involves altering the conditions of test while decarburizing and denitriding alters the chemical composition. This means that, strictly speaking, the results obtained are not directly comparable with the original S/N curve.

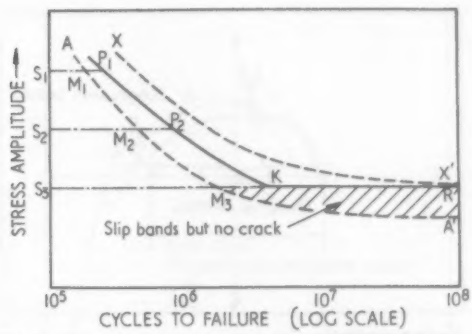
It was thought that a better method of examining the validity of Fig.3 might be to utilize the 'understressing' and 'coaxing' effects which are thought to be a consequence of the strain ageing ability of steel.[7]

In 'understressing', a specimen is subjected to several million cycles of stress below the fatigue limit. This has been found to increase the life in a subsequent test above the fatigue limit.

'Coaxing' is a type of progressive understressing. A specimen is given a large number of cycles (usually 20 million or more) below the fatigue limit and the stress is then increased to a slightly higher value. A further 20 million cycles are then applied and the stress raised again. The process is repeated until



2 *S/N curve with a knee*



Note: The three S/N curves are obtained under the following conditions

A–A′	Material not allowed to age during the test
X–X′	Material aged before starting the test but not allowed to age during the test
P_1P_2KR	As obtained in practice-material strain ageing during test

3 *Effect of strain ageing occurring during fatigue test*

failure occurs. Spectacular increases in fatigue strength can be achieved by this means.

The amount by which the stress is raised each time is called the *stress increment* and the number of cycles at each stress is called the *cycle increment*.

Sinclair[7] has shown that the smaller the stress increment and the larger the cycle increment, the greater is the improvement in fatigue strength. He has also shown that the strengthening is confined to those materials which are capable of strain ageing. This suggests that the coaxing effect is caused by progressive strain ageing of the material at every successive stress level, the material being below the new fatigue limit each time.

The object of the present experiments was to try to exhaust the strain ageing ability by a coaxing procedure, short of fracture, and then to re-test the specimens at yet higher stresses to find their new S/N curve. If the hypothesis of Fig.3 is correct this latter curve should be smooth and fractures should be encountered at more than 3–4 million cycles at which the knee usually occurs. In this way it should be possible to reach the curve X–X'.

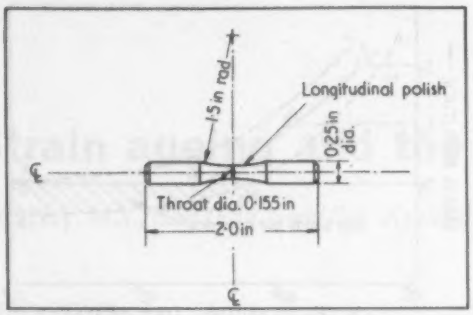
A further object of the investigation was to examine the tensile behaviour of the material in order to discover whether a correlation existed between the strengthening due to coaxing in fatigue and the strengthening due to strain ageing in tension.

MATERIAL AND APPARATUS

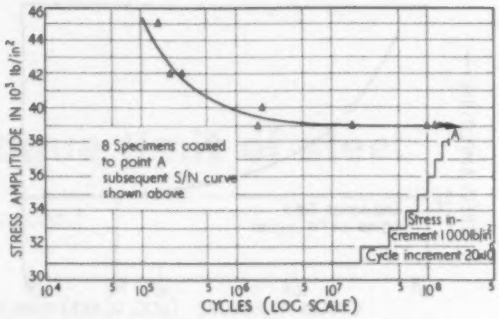
The material used was a rimming steel supplied by the British Iron and Steel Research Association from their stock held for research purposes. It had the following chemical composition:

Constituent	C	Ni	Mn	S	P
wt-%	0·11	0·0033	0·50	0·021	0·02

The material came from the lower part of a 3-ton 18-cwt billet that was reduced in one heat to 2 in² billets, one of which was rolled in $\frac{9}{32}$ in × 12 ft rod. The specimens were cut from these and turned. After machining they were given a stress relieving treatment by heating to 450°C for 24 h and cooling in the furnace. They were then polished longitudinally with successively finer grades of emery over the test section. The dimensions of the finished specimen are shown in Fig.4.



4 *Fatigue specimen*


STRESS AMPLITUDE IN 10³ lb/in²
8 Specimens coaxed to point A subsequent S/N curve shown above
Stress increment 1000 lb/in²
Cycle increment 20×10⁶
CYCLES (LOG SCALE)

6 *Stress history and S/N curve of coaxed material*

Two fatigue machines of the rotating cantilever type were used. Results on these were compared statistically before commencing the main tests and no significant difference was found. The testing was shared equally between the two machines.

RESULTS AND DISCUSSION

The S/N curve

The ordinary S/N curve of the material based on about 50 results is shown in Fig.5. At low stress amplitudes the specimens either failed in less than about 6 million cycles or else survived 100 million at which the tests were stopped. This clearly indicated the existence of a definite fatigue limit, shown at 33750 lb/in², the knee being at about 4 million cycles.

Coaxing tests

Twelve specimens* were coaxed from a starting stress amplitude of 31000 lb/in², with a cycle increment of 20 million cycles and a stress increment of 1000 lb/in² up to and including 38000 lb/in².

Four specimens did not survive this treatment and failed between 31000 and 38000 lb/in². The eight survivors were tested at different stress levels above 38000 lb/in² and their S/N curve, together with the coaxing history, is shown in Fig.6. This curve appears to be smooth and without a knee.

Compared with Fig.5 there is a significant increase life at any given stress level. For example at 45000 lb/in² the *maximum* life of nine specimens of the virgin material was 98000 cycles whereas the coaxed specimen ran 149000 cycles. At 40000 lb/in² the maximum life of 17 of the virgin specimens was 680000 cycles and the previously coaxed specimen ran 1893000.

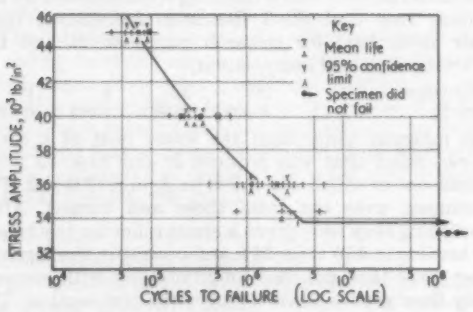
For the coaxed specimens tested at 39000 lb/in² there were four results. Two survived 100 million cycles and two broke at 1668000 and 16092000 cycles respectively. (This last figure is much greater than any failure point on the ordinary S/N curve.) A further coaxing procedure was undertaken on the two survivors. Again the stress was raised by increments of 1000 lb/in² but the cycle increment was increased to 100 million. One specimen failed at 41000 lb/in² after 95 million cycles at that stress, the other at 43000 lb/in² after 89 million cycles at that stress.

The incidence of failures at close to 100 million cycles is strong evidence that the knee has been removed by the coaxing procedure. A more complete version of Fig.3 can be used to illustrate this in more detail.

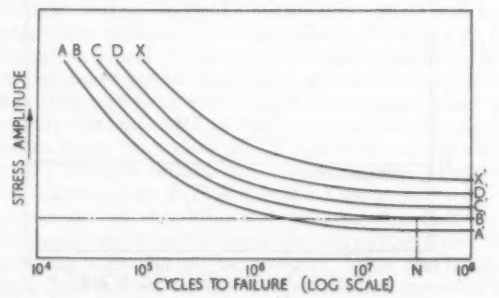
In Fig.7 a series of smooth S/N curves are depicted. Again the curve A–A' is obtained for the non-strain aged material and X–X' for material fully strain-aged before the fatigue test. The curves B–B', C–C', D–D' correspond to material given intermediate amounts of strain ageing and the actual S/N curve would be defined by a series of points on these different curves.

Consider a specimen tested at stress amplitude S. It can fail after N cycles provided that the material shifts exactly to the curve B–B' after N cycles. But beyond 10 million cycles the smooth S/N curves become very nearly parallel to the N axis and this makes such a coincidence practically impossible. If the material shifts to another curve such as C–C' after N cycles, there will be no fracture and by the time the

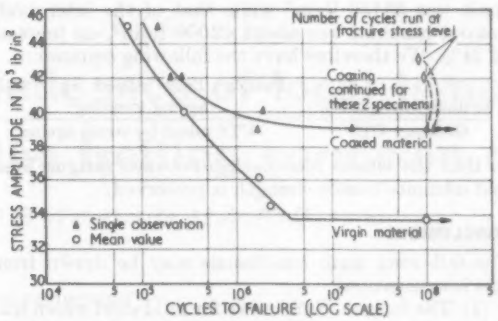
* The relatively small number used for this part of the work is due to the length of each coaxing test. In the same machine time as finally used for these 12 specimens, more than 250 specimens could each have been endurance tested for 10 million cycles.



5 *S/N curve of virgin material*



7 *S/N curves of constant strain ageing*


STRESS AMPLITUDE IN 10^3 lb/in^2
CYCLES TO FAILURE (LOG SCALE)
Number of cycles run at fracture stress level
Coaxing continued for these 2 specimens
Coaxed material
Virgin material
Single observation
Mean value

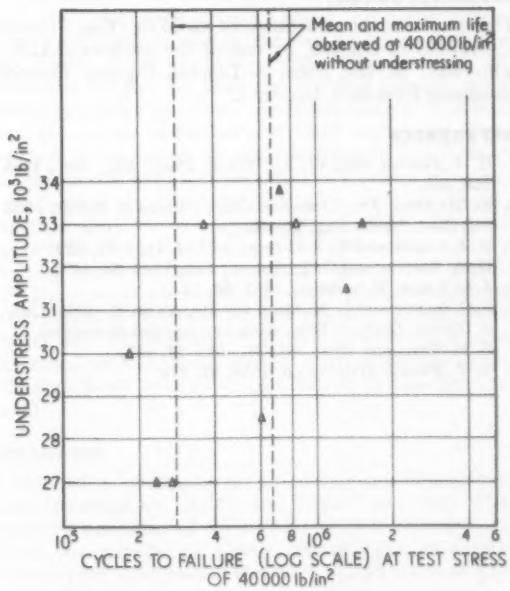
8 *Removal of the knee by coaxing*

stress amplitude S intersects C–C', at a very much greater number of cycles, the material would have shifted to a yet higher curve.

The flatness of the curves beyond about 10^7 cycles makes a long failure conceivable only in the theoretical sense, if a knee is present in the ordinary S/N curve. Gough has expressed his 'feel' of such a situation without giving an explanation for it; 'Such long endurances to failure are most uncommon, and if one set out to get such a failure years might be spent in the attempt'.

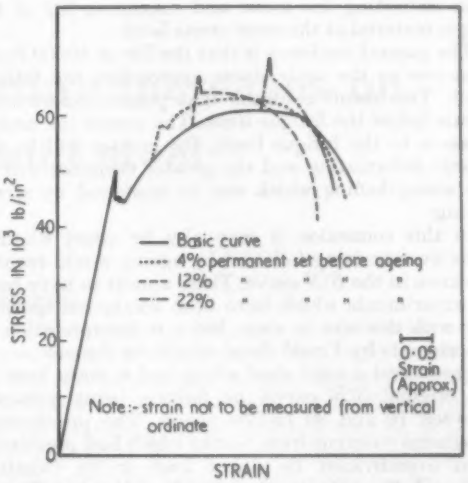
An unusually long life to fracture can therefore be taken as a practical criterion of the absence of a knee in the S/N curve of a metal. In the present series of tests not one but *four* such long lives were encountered after coaxing. They are recapitulated below:

Failing stress, lb/in²	Cycles at failing stress
43000	89440000
41000	95340000
39000	16090000
34000	15250000


UNDERSTRESS AMPLITUDE, 10^3lb/in^2
CYCLES TO FAILURE (LOG SCALE) AT TEST STRESS OF 40000 lb/in^2
Mean and maximum life observed at 40000 lb/in^2 without understressing

Note: The understress cycles were 10^6 in each case
original fatigue limit $\pm$33750 lb/in²

9 *Effect of single fatigue understressing on subsequent life at 40000 lb/in²*


STRESS IN 10^3 lb/in^2
STRAIN
Basic curve
4% permanent set before ageing
12% " " "
22% " " "
0·05 Strain (Approx.)
Note:- strain not to be measured from vertical ordinate

10 *Effect of single ageing on tensile strength*

The last specimen here was one of those which failed before completing the coaxing programme to 38000 lb/in² and so may be classed as relatively weak. However it failed after 15 million cycles at its final stress level which indicates that, so far as exhausting the strain ageing ability is concerned, coaxing has qualitatively the same effect on both strong and weak specimens.

Figure 8 shows a composite picture of the results presented in Figs.5 and 6. Since only 8 out of 12 specimens completed the coaxing run, the upper curve shows the effect of coaxing on the top $\frac{2}{3}$ (in strength) of all specimens. It represents in fact a curve such as D–D' of Fig.7 for these specimens. Again, out of the four specimens run at 39000 lb/in², the two which survived must represent approximately the top $\frac{1}{2}\times\frac{2}{3}=\frac{1}{3}$ in strength of all specimens. The lives of these two at their final failing stresses are shown in Fig.8. They fall on a yet higher S/N curve corresponding approximately to the fully strain aged curve X–X' of Fig.7.

To discover whether an 'artificial' strain ageing treatment applied periodically can be substituted for part of the cycle increment in coaxing, a few specimens were coaxed with cycle increments of only 2 million or 10 million cycles but between each stress increment they were strain aged by heating to 100°C for about 1 h. All these specimens failed before reaching 38000 lb/in² and all failed before 3 million cycles at their final stress.

This shows that as far as the coaxing effect is concerned part of the cycle increment cannot be replaced by static ageing. A 20 million cycle increment seems to be necessary to offer a chance of survival at 38000 lb/in². It is of interest that this is about the same number of cycles as needed to produce a constant damping capacity and to establish a stable slip band pattern below the fatigue limit.

Understressing tests

A supplementary series of understressing tests was conducted in which specimens were given 100 million cycles below the fatigue limit and were then tested at 40000 lb/in². Figure 9 shows the results together with

lines indicating the mean and maximum life of the virgin material at the same stress level.

The general tendency is that the life at 40000 lb/in² increases as the understress approaches the fatigue limit. This result confirms that plastic deformation occurs below the fatigue limit. The nearer the understress is to the fatigue limit, the greater will be the plastic deformation and the greater therefore will be the strengthening which can be conferred by strain ageing.

In this connexion it may also be asked whether *static* overstraining followed by ageing would remove the knee in the S/N curve. There appear to have been no experiments which have been conducted specifically with this aim in view, but a re-interpretation of experiments by Frost[8] shows this to be the case.

Frost used a mild steel which had a sharp knee in the original S/N curve, no failures being obtained between 10 and 80 million cycles. The pre-stressed specimens were cut from blanks which had previously been overstrained by direct load or by twisting. Although Frost shows a knee in the S/N curves for the overstrained material, there were in fact four long life failures at about 30 million cycles so that the existence of a knee is very doubtful. It is interesting also, that while the ferrous metal showed an increase in strength, non-ferrous metals, tested in a similar way, did not. This is another indication that strain ageing, not merely work-hardening, is the principal cause of the strengthening.

The common factor between Frost's tests and the present coaxing tests is that the steel is permitted to strain age fully before the final fatigue test and therefore exhibits a smooth S/N curve characteristic of non-strain ageing materials.

Tensile tests

All tensile tests were carried out on a Hounsfield Tensometer. The specimens, which were about 1 in long, were machined from untested fatigue specimens.

Figure 10 shows the basic stress–strain curve and also the effect of a single intermediate ageing. For these latter tests a specimen was plastically strained by either 4, 12, or 22%, then heated for 1 h at about 100°C. The change in the stress–strain curves shows that both the yield and ultimate stresses are raised by this procedure, there being a greater increase for greater amounts of permanent set before ageing.

In further tensile tests some specimens were given a small permanent set, then aged (as before) and the process repeated until failure occurred. This treatment increased the ultimate tensile strength by about 22%, and is about the same percentage increase as obtained in the fatigue limit by coaxing. The original fatigue limit was 33750 lb/in² while that of the intensively coaxed material was about 42000 lb/in², an increase of 24%. We therefore have the following equation:

$$\frac{\text{Ordinary fatigue limit}}{\text{Ordinary UTS}} = \frac{\text{Fatigue limit raised by strain ageing (coaxing)}}{\text{UTS raised by strain ageing}}$$

so that the classic relationship between fatigue limit and ultimate tensile strength is preserved.

CONCLUSIONS

The following main conclusions may be drawn from this investigation:

(1) The fatigue (S/N) curve for mild steel which had been subjected to prior coaxing showed continuous failures up to 100 million cycles. This indicates that the knee in the S/N curve of steel can be eliminated by prior fatigue stressing and is consistent with the idea that a definite fatigue limit in steel is caused by its ability to strain age during a fatigue test. If the strain ageing capability is exhausted by the coaxing procedure, the knee in the curve can be removed.

(2) The existence of a fatigue limit (as distinct from an endurance limit) in steel can be explained by postulating a series of smooth S/N curves each representing the fatigue behaviour at a specific stage of strain ageing. This concept agrees with the fact that slip bands occur below the fatigue limit and also with the X-ray and damping characteristics.

(3) The percentage increase in the fatigue strength of mild steel due to coaxing was the same as the percentage increase in UTS due to repeated strain ageing in an interrupted tensile test. This is additional indirect evidence that strain ageing is responsible for the coaxing effect and consequently for the knee in the S/N curve.

ACKNOWLEDGMENT

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Influence of local temperature increases on the fretting corrosion of mild steel

R. B. Waterhouse, M.A., Ph.D., F.I.M.

SYNOPSIS

X-ray back-reflexion photographs of fretted areas on the ground surface of a bright drawn mild steel indicated that the steel had recrystallized in these regions. Comparison with back-reflexion photographs of similarly prepared surfaces after annealing at various temperatures in an inert atmosphere showed that the same degree of recrystallization was produced by heating in the range 450°–500°C. The temperature of the transition of γ Fe_2O_3 *to* α Fe_2O_3, *which is the main constituent of fretting corrosion debris on mild steel, was also found to be in the neighbourhood of 500°C. It is suggested that the severe plastic deformation occurring in the fretting of two steel surfaces dissipates sufficient energy to cause a temperature rise of this magnitude in the surface layer.* 1918

INTRODUCTION

THE OBSERVATIONS recorded in this paper form part of an investigation into the effect of fretting corrosion on the fatigue strength of mild steel. Although it is a common observation that fatigue cracks frequently originate in regions of fretting corrosion, investigations of the influence of fretting corrosion on fatigue life are relatively few. Warlow-Davies[1] found a reduction of 13% in the fatigue limit of mild steel specimens which were submitted to fretting within the gauge length and then tested in a fatigue machine. More recently Fenner and Field[2,3] have investigated the effect of fretting corrosion occurring during the fatigue test on the total life of aluminium alloy specimens of the Duralumin type. If the specimens were subjected to fretting corrosion during the first 20000 cycles of the fatigue test the total life was reduced to 100000 cycles in conditions where the specimen would survive 20 million cycles in the absence of fretting corrosion. Increase in the number of cycles of fretting had little influence on the total life of the specimen. The inference is that fatigue cracks are initiated early on in the fretting period and the life of the specimen is determined by the rate of propagation of these cracks.

The influence of fretting on fatigue could be twofold: (*a*) the surface roughening produces stress raisers, (*b*) conjoint action between fretting corrosion and cyclic stressing (comparable with the case of corrosion fatigue) so that the fretting process itself produces cracks by a form of surface fatigue. The fact that the curves of Fenner and Field show some similarity with the curves obtained by Simnad and Evans[4] in their investigation of the effect of a period of corrosion fatigue on the total life of a steel specimen, suggests that (*b*) is the important effect. Talysurf surveys by the author[5] of typical surfaces damaged by fretting corrosion have previously shown that generally the type of pit produced would not cause serious concentration of stress. In the present investigation fretted and fatigued specimens of mild steel have been examined with the metallurgical microscope and back-reflexion X-ray in an attempt to clarify the mechanism in (*b*).

APPARATUS

A four-point-loading rotating-bending machine of the type described by Huddle and Evans[6] was used. The specimen consisted of a $\frac{3}{8}$ in dia. rod 14 in in length on which two parallel flats were ground $1\frac{1}{2}$ in in length reducing the thickness of the shaft at this point to $\frac{1}{4}$ in and positioned so that the gauge length thus produced lay between the two centre load carrying bearings, i.e. in the constant bending moment region. The ends of the flats were given a 2 in radius to avoid an abrupt change in section. The fretting device was similar to that used by Fenner and Field and consisted of two bridge pieces of the same material as the specimen, $\frac{3}{4}$ in in length with a rectangular flat at each end $\frac{1}{32}$ in^2 in area, which were clamped on to the gauge length of the specimen (after degreasing in trichlorethylene) with a proving ring which enabled the clamping pressure to be adjusted. A given load and clamping pressure were used throughout the tests, thus giving a fixed average amplitude of slip. The fretting device was applied at the beginning of a test and the machine run for a certain number of cycles. It was then removed and the fatigue test was continued with the same load until the specimen failed. The details of the material and the loading conditions are given in Table I.

RESULTS

Before the fretting bridges were removed in the cases of the longer fretting times, the typical reddish brown powder was observed oozing from the contact region. An X-ray powder photograph showed that the material was a mixture of α Fe_2O_3 plus a little metallic iron. In every case it was found that a certain amount of force had to be applied to break the fretting bridges from the specimen surface. The contact area showed signs of pitting and the typical reddish brown stain.

The curve relating number of fretting cycles to total life is shown in Fig.1. The shape of the curve is similar to those obtained by Fenner and Field with aluminium alloys.

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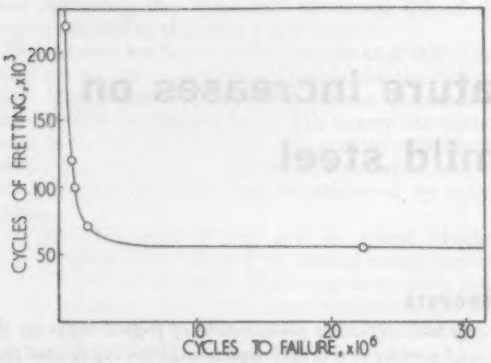


1 *Graph of number of fretting cycles* v. *number of cycles to failure*

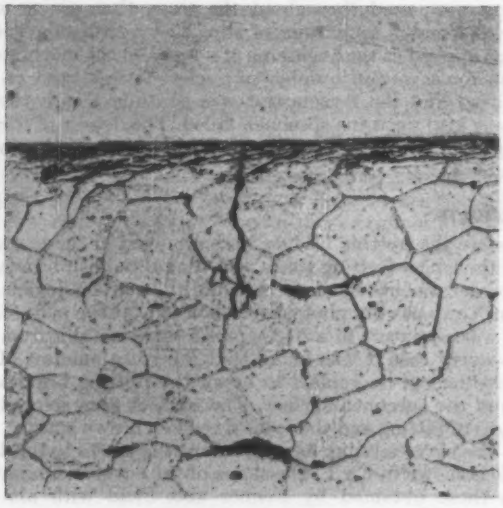
Without exception failure of the specimens occurred across one of the fretted regions. The failed specimens were prepared for micro-examination by first degreasing and then giving them a heavy coat of electrodeposited nickel (about 0·050 in), to protect the surface during sectioning and to prevent bevelling in subsequent polishing. The specimen was then sectioned in a plane parallel to the axis and at right angles to the two flats, and examined after polishing and etching in 2%Nital. In most cases a survey was made over the entire fretted region by consecutive removal of 0·005 or 0·010 in from the surface by grinding, and polishing, and examined after each removal.

Micro-examination

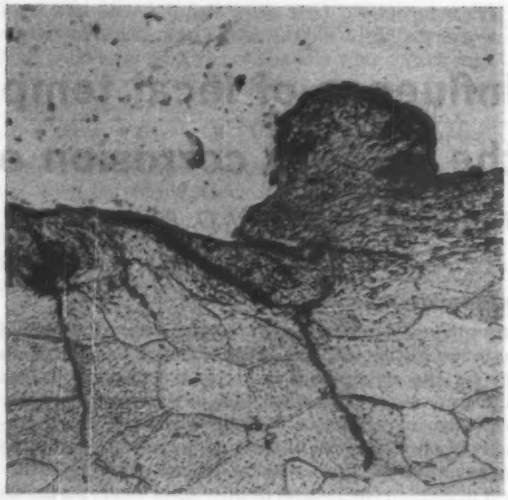
Numerous fatigue cracks were found originating from the part of the surface of the specimen which had been subjected to fretting corrosion. Fatigue cracks with their sources in other parts of the surface were extremely rare. An example of one of them is shown in Fig.2. The surface of the specimen consists of pure ferrite with relatively few areas of pearlite. The actual surface layer shows some distortion due to the machining of the flat, but the surface itself is reasonably flat. The fatigue crack has no obvious point of initiation, but it must be remembered that the actual point of origin may be in another plane from that of the section. The plane of the crack is at right angles to the direction of the principal stresses. In the fretted regions considerable disturbance of the surface is observed (Figs.3, 4, and 8). The material has undergone severe plastic deformation, indicated by the obliteration of the grain structure and the raising of some regions above the general level of the surface. In addition fatigue cracks are visible. They tend to run

TABLE I Bright drawn mild steel

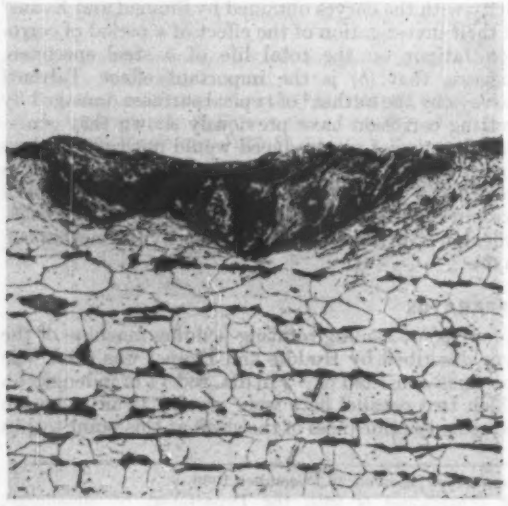
Composition	0·16%C, 0·58%Mn
UTS	40·3 tons/in²
Clamping pressure	2560 lb/in²
Surface stress	16 tons/in²
Nominal slip	0·0014 in



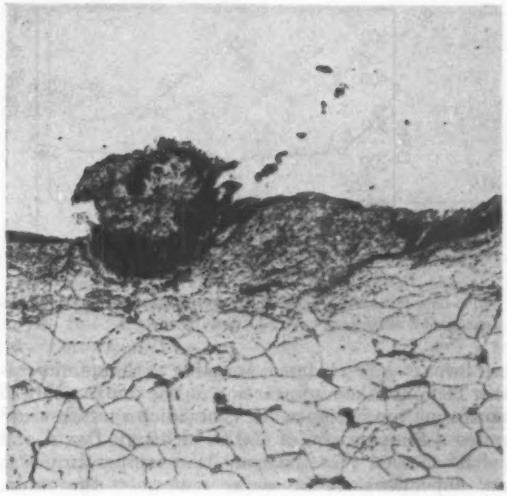
2 *Normal fatigue crack*



3 *Surface damage (120 000 cycles of fretting)* ×400



4 *Surface damage (120 000 cycles of fretting)* ×200



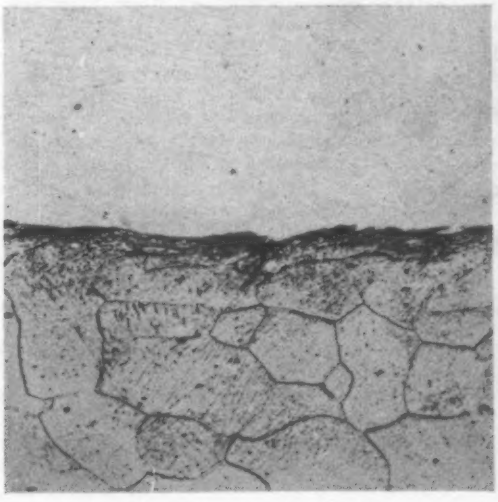
5 *Surface damage (120000 cycles of fretting)* ×200

obliquely to the surface in the highly distorted region but on reaching the unaffected material their direction changes and becomes more nearly perpendicular to the direction of the principal stresses (Figs.3 and 7).

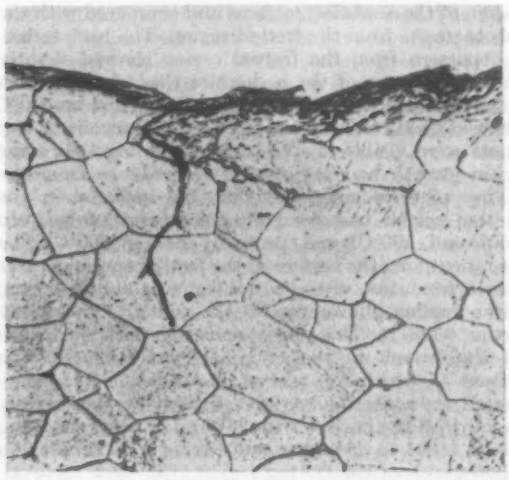
It is frequently observed that two sets of inclined cracks tend to run into one another. This would result in the removal of a portion of the surface, a stage which is almost reached in Fig.4. On two occasions a particle of iron torn from the bridge piece has been found welded to the specimen surface. Figure 5 shows one example.

The presence of cracks in the fretted region has been observed even after relatively few cycles of fretting as shown in Figs.6 and 7. (number of fretting cycles= 10000). The distorted zone is much narrower than with longer fretting times, but the severe working of the surface has been sufficient to initiate fatigue cracks.

Several hardness traverses were made of the distorted region with a GKN micro-hardness tester, to discover whether appreciable work hardening had taken place. Figure 8 is a photograph of a line of indentations made at intervals of 1/1000 in and the results are plotted in Fig.9. Surprisingly, very little hardening has occurred. Only the point immediately inside the surface shows any significant increase and this is probably due to the constraining effect of the adjacent much harder nickel layer.



6 *Surface damage (10000 cycles of fretting)* ×400



7 *Surface damage (10000 cycles of fretting)* ×400

A number of microhardness traverses were also made on the surfaces of specimens after removal from the fatigue machine, across the region of fretting. The result of one such traverse on a specimen which had suffered 220000 cycles of fretting is shown in Fig.10. The distance between the two peaks in the curve corresponds to the width of the foot of the bridge piece indicating that some hardening occurs at the edges of the contact areas of the bridge pieces, but that there is no hardening in the centre where the pitting usually occurs.

X-ray examination

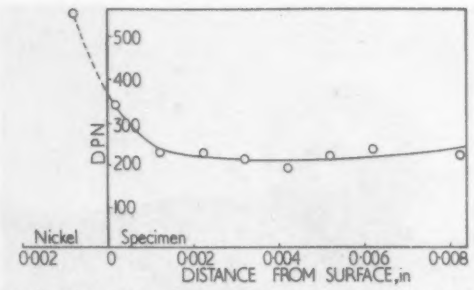
A series of back-reflexion photographs was taken with cobalt Kα radiation at intervals of 0·010 in across the fretted region of the specimen on which the hardness traverse was made. The photographs from the unfretted surface show no resolution of the α doublet of the (310) line indicating the presence of some work hardening from the machining of the flat. The photographs from the centre of the fretted region, on the other hand, show good resolution of the doublet indicating that the material has recrystallized in the region of fretting. This suggests that a considerable rise in temperature has occurred during fretting.

In order to make an assessment of this temperature rise, a series of specimens of the steel were prepared with the same surface finish as is produced in the machining of the flats, and these were annealed at various temperatures between 300 and 600°C in a nitrogen atmosphere for 2½ h. This length of annealing time was chosen because it approximated to the length of time for which the bridge pieces were applied to the specimen which was the subject of the X-ray back-reflexion traverse. Back-reflexion photographs were

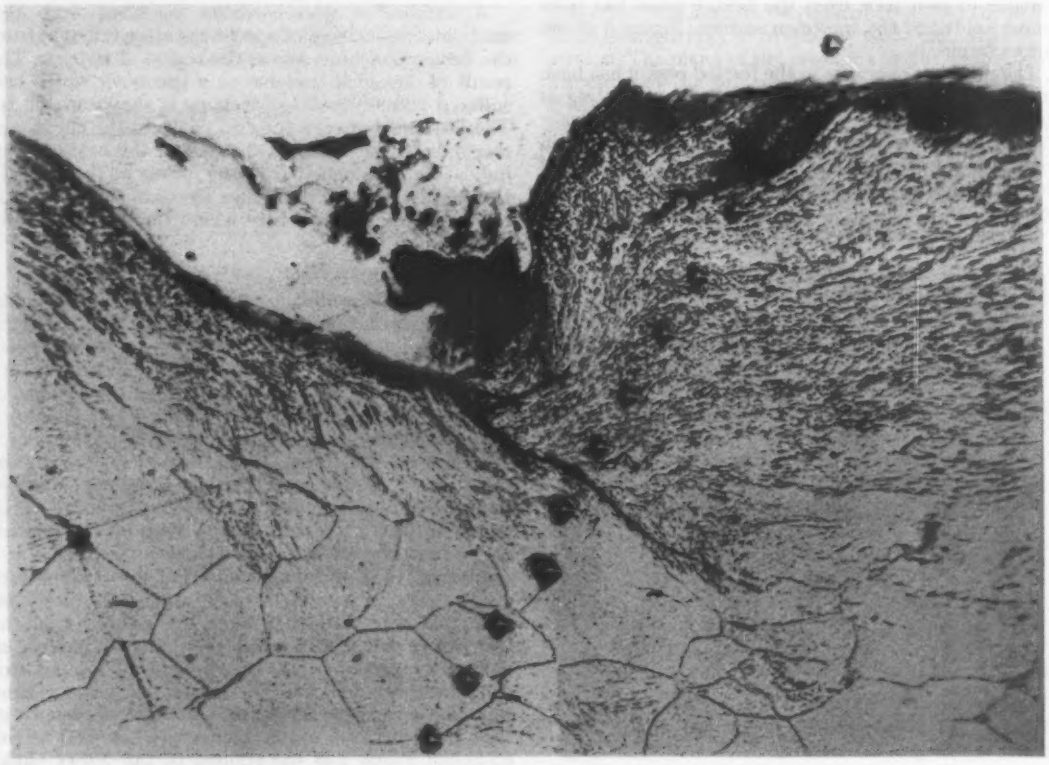
taken of the annealed surfaces and compared with the photographs from the fretted region. The back-reflexion pattern from the fretted region showed slightly more resolution of the α doublet than the specimen annealed at 450°C. The specimen annealed at 500°C showed good resolution of the doublet but one or two spots were visible on the rings indicating that some grain growth had occurred. The evidence from the X-ray pictures suggested that the material in the fretted region had been at a temperature between 450° and 500°C, and probably nearer 500°C. The distance along the surface of the fretted specimen over which resolution of the α doublet was obtained was, after making allowances for the width of the X-ray beam, 0·065 in. This corresponds well with the length of the trough in the microhardness traverse. The extent to which the recrystallized region had penetrated the material was investigated by successively etching off the surface with 25% nitric acid, removing about 0·001 in at a time and taking a back-reflexion photograph of the fretted region after each removal. After removal of 0·005 in, the pattern was identical with that obtained from the centre of the steel, which also showed no resolution of the α doublet in line 310 due to cold work from the bright drawing process.

X-ray studies of the α and γ modifications of Fe_2O_3

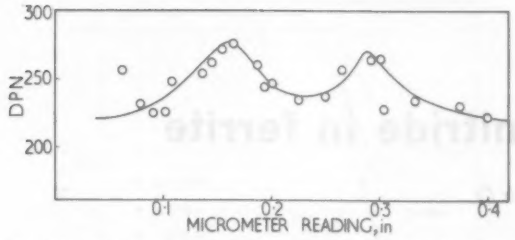
Many investigators have demonstrated that the reddish-brown powder that constitutes the bulk of the debris, formed as a result of the fretting corrosion of mild steel, is α Fe_2O_3. The air-formed oxide film on mild steel is, however, the γ form. The high temperature form is α Fe_2O_3 but it is stable at room temperature. The published information on the temperature of transformation is somewhat contradictory. Sidgwick[7] quotes a temperature of 600°C, although David and Welch[8] showed that the transition temperature was very dependent on the water content of the oxide. Mackay[9] states that the γ oxide prepared from lepidocrocite and heated at 100°C/h begins to transform at 290°C and is completely transformed at 440°C. When the oxide is examined on the surface of a piece of pure iron the α oxide appears at a much lower temperature, i.e. in the region of 200°C.[10] At 300°C the layer consists of an outer layer of α Fe_2O_3 over an inner layer of the cubic oxide. Since the examination of thin films in contact with the metal is not possible by X-ray diffraction it was decided to investigate the transition



9 *Microhardness traverse of the section shown in Fig.8 (120 000 cycles of fretting)*



8 *Microhardness traverse across fretting damage (120 000 cycles of fretting)* ×400



10 *Microhardness traverse along the surface across the fretted area (220 000 cycles of fretting)*

on the bulk material by heating samples for 2½ h at various temperatures.

A sample of γ Fe_2O_3 was prepared by precipitating $Fe(OH)_2$ from a solution of ferrous sulphate with excess ammonia, filtering off and heating the precipitate in air for 16 h at 300°C. The resultant brown powder was strongly ferromagnetic and an X-ray powder photograph corresponded closely with the published patterns for γ Fe_2O_3. However, magnetite is also strongly ferromagnetic and has an almost identical pattern as γ Fe_2O_3; to make sure that the sample was not magnetite a little was dissolved in HCl and tested for the presence of ferrous ions with potassium ferricyanide. No trace of the blue colouration was detected whereas a sample of magnetite treated similarly showed an intense blue colour. Samples of the γ Fe_2O_3 were heated in air at various temperatures for 2½ h, and then investigated by the X-ray powder method. The specimen heated at 550°C was entirely non-magnetic, reddish in colour and the pattern corresponded to α Fe_2O_3. The sample heated at 480°C was still magnetic but the colour was more reddish than the original γ. The pattern of this specimen, however, was predominantly α with one faint line corresponding to γ. Samples heated at temperatures below 480°C were entirely γ. The evidence from these tests is that γ Fe_2O_3 is beginning to transform to α in the region of 480°C. It is possible that the extremely high pressures to which the debris is subjected in fretting corrosion may modify the transition temperature.

DISCUSSION

It has been stated[11] that since severe fretting can be produced between a mild steel surface and a polymethacrylate plastic (mp 80°C) without there being any sign of softening of the plastic, that temperature effects are not important in fretting corrosion. More recently Fenner and Field have shown that the fretting corrosion produced on the surface of an aluminium alloy by an alumina mating surface is much less effective in initiating fatigue cracks than fretting produced by an aluminium alloy mating surface. The distinction between the two cases is that in the latter the two metallic surfaces are capable of welding together whereas in the former they are not. Evidence of this welding has been provided by Fenner and Field and also by the present results. The welding of the two surfaces results in very severe working of the surfaces well above the plastic range. At the frequencies encountered in fretting it is reasonable to suppose that this cyclic straining of the surface results in the evolution of considerable heat. The fact that the mild steel used in this investigation shows signs of recrystallization in the fretted region, and that the oxide debris is α Fe_2O_3 which is not formed until the temperature is in the region of 500°C supports this idea. An attempt was made to calculate whether such a temperature rise was possible. Assuming the temperature at a depth of 0·005 in from a point source of heat after 2½ h was 500°C, the magnitude of the source was calculated as 8·5 cal/s. The stress system under the feet of the bridge was too complicated for it to serve as a basis for the calculation of the energy liberated. Instead it was assumed that the heat was solely produced by friction. In order to generate 8·5 cal/s the value of the coefficient of friction would have to be about 50. This is unusually high. However, when it is considered that the bridges had to be broken off the specimen due to welding, such a value may not be so unlikely. Bowden and Tabor[12] record coefficients of friction of the order of 100 in cases where great care is taken in removing oxide films, a situation in which welding also occurs on a large scale. This rise in temperature together with the severe stressing conditions in the affected region would be expected to give a very low fatigue life. Cazaud[13] quoting some results of Kaufman, shows that the fatigue limit of a mild steel at room temperature is 28 tons/in² whereas at 550°C it is reduced to 14 tons/in². Fretting produced without welding, as in the case of a non-metal fretted against a metal, would not produce the severe local fatiguing of the surface nor the severe plastic deformation resulting in the temperature rise and would consequently not be expected to have much effect on the fatigue strength, as observed by Fenner and Field. The damage produced in such cases is probably due solely to abrasion.

ACKNOWLEDGMENTS

The author would like to thank Messrs B. A. Watkinson and P. T. D. Williams who carried out the fatigue tests as part of their Finals Honours project in the Department of Mechanical Engineering, University of Nottingham, and Dr P. A. Brook for electroplating the specimens.

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The solubility of silicon nitride in ferrite

R. Rawlings, Ph.D., F.I.M., and P. M. Robinson, Ph.D.

SYNOPSIS

The nitrogen in solid solution in ferrite in equilibrium with silicon nitride has been determined by means of internal friction of wires containing 0·5%, 1·1%, and 1·9%Si. At any temperature in the range 600–900°C the solubility product [Si]³ [N]⁴ *is the same for the 0·5%Si and the 1·1%Si alloy. The values for the third alloy are slightly different. The heat of solution of silicon nitride for the first two alloys is 14·7 kcal/gmol, and for the third 29 kcal/gmol. The activity coefficient of silicon is calculated and is similar to that recently determined by Pehlke and Elliott.* 1913

INTRODUCTION

THE SUBJECT HAS recently been reviewed in detail by Leslie[1] and need be only briefly reviewed here. Using a gas–metal equilibrium method, Turkdogan and Ignatowicz[2] determined the nitrogen in solid solution in equilibrium with silicon nitride. Their results are given in Table I.

In spite of the fact that the authors made every effort to ensure equilibrium between ferrite and precipitate, some anomalies, pointed out by Seybold and by Cameron and Oates[3] indicated that in fact equilibrium was not reached.

Using a chemical method of determining the nitrogen in solution as well as the total nitrogen, Fryxell *et al.*[4] found the results below, with 3·25%Si:

Temp., °C	800	900	1000	1100
N, %	0·0006	0·0011	0·0019	0·0029

These results were criticized by Leslie and Momeyer.[5] It is unnecessary to discuss these papers further in view of the detailed discussion already published.

As is now well known, interstitial atoms in solid solution give rise to a peak in the internal friction temperature curve. In the case of iron–silicon alloys several peaks occur.[6] The experimental curve may be resolved mathematically into its component parts, each part having the same characteristic shape given by the formula:

$$\omega\tau/(1+\omega^2\tau^2)$$

where ω is the angular frequency of vibration, and τ is the relaxation time of the process causing the internal friction. In the case of binary alloys the height of the internal friction peak is proportional to the concentration of interstitial atoms in solid solutions[7] and it is reasonable to suppose that the sum of the heights of the peaks for a ternary alloy is proportional to the concentration of interstitial atoms in solid solution. This was assumed by Leake *et al.*[8] and the present results lend some support to the assumption. Nevertheless it is an assumption.

Assuming this, the method to be described is to load an iron–silicon alloy with nitrogen and to follow the precipitation of silicon nitride using internal friction. When the latter results are constant after repeated annealings, it is assumed equilibrium between nitride and ferrite has been reached and that the internal friction is a measure of the nitrogen remaining in solid solution. By means of a separate series of experiments the relationship between concentration of nitrogen and internal friction is determined so that the nitrogen concentration in equilibrium with silicon nitride can then be calculated.

Manuscript received 5 January 1961.

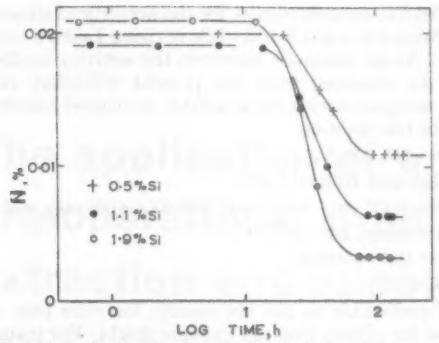
The authors were with the Department of Metallurgy and Fuel Technology, University College, Cardiff, when this paper was written. Dr Robinson is now with John Lysaght (Aust.) Pty, Ltd, Central Research Laboratories, Newcastle, NSW, Australia.

EXPERIMENTAL

The alloys were made of high-purity iron and silicon and the method of preparation is given in a previous paper.[6] The alloys used contained 0·5, 1·1, 1·9, and 2·4%Si respectively. The latter alloy was used only in the calibration experiment. The internal friction was measured for a frequency of about 1 c/s and the strain was such that the internal friction was amplitude independent. The method of measurement is given in ref.6. Specimens 0·02 in thick were heated in dry flowing hydrogen until there was no trace of the carbon or the nitrogen peak in the internal friction/temperature curve.

These were then heated for 70–120 h in partially cracked ammonia, the internal friction/temperature curve being determined after various intervals of time. The curves were analysed into their component peaks and the sum of the peaks plotted against nitriding temperature. A typical plot is shown in Fig.1 for 800°C. It can be seen that the sum of the peak heights decreased after some time and then remained constant. This constant value corresponds to the nitrogen in solution and from its constancy it is presumably in equilibrium with the precipitated nitride. It was determined for temperatures in the range 600–900°C for the 0·5, 1·1, and 1·9%Si alloys.

To find the relationship between the nitrogen content and internal friction more specimens were nitrided at 800°C for only 4 h, i.e. before precipitation began. After quenching in water the internal friction/temperature curve was determined and the wires analysed for nitrogen. The nitrogen content was determined by the steam distillation Keldjahl method, solution being by dilute HCl assisted where necessary by a few drops of HF concentration in equilibrium with the precipitated nitride.



1 *Variation of nitrogen in solution (calculated from sum of internal friction peaks) with time at 800°C*

RESULTS

The plots of nitrogen content against the sum of the internal friction peaks are given in Fig.2. Because of the small concentrations of nitrogen found in the 1·9% and the 2·4% alloys these results are much more inaccurate than those for the alloys of lower silicon content. The results in Fig.2 are summarized in the following equations:

$\%N = 0{\cdot}86\Sigma$log dec. for 0·5%Si alloy
$\%N = 0{\cdot}43\Sigma$log dec. for 1·1%Si alloy
$\%N = 0{\cdot}05\Sigma$log dec. for 1·9%Si alloy
$\%N = 0{\cdot}04\Sigma$log dec. for 2·4%Si alloy

All these factors are lower than that for binary iron–nitrogen alloys, the last two being surprisingly low.

Using these factors the nitrogen remaining in solid solution after long nitriding times was calculated (*see* Table I). No attempt was made to determine the solubility for the 2·4%Si alloy owing to the low nitrogen contents involved.

The total nitrogen content was determined by chemical analysis (Table II, col. 1) and was also calculated from the internal friction curve determined before the precipitation of silicon nitride (Table II, col. 2).

The solution of silicon nitride in ferrite may be represented by the equation

$$Si_3N_4 = 3[Si] + 4[N]$$

and provided the precipitate is always of the same composition then equilibrium may be represented by the equation

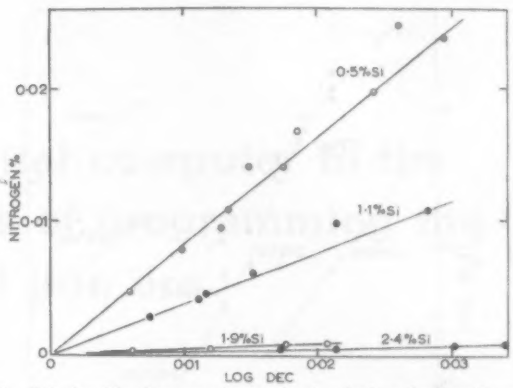
$$K = [Si]^3[N]^4$$

neglecting for the moment the variation in activity coefficients with concentration.

Log K has been plotted against I/T in Fig.3, with other workers' results for comparison. Results for the 0·5% and 1·1%Si alloys are very close and ΔH, the heat of solution, is 14·7 kcal/gmol. For the 1·9%Si alloy, however, ΔH is found to be 29 kcal/gmol. Because of the low nitrogen contents involved in calculation of the latter, no great reliance can be placed on it.

TABLE I Results of Turkdogan and Ignatowicz

Temp., °C	Si, %	N, %
500	0·90	0·0060
500	1·26	0·0017
600	0·90	0·0120
600	1·26	0·0034
600	2·83	(0·0003)
705	2·83	0·0009



2 *Relationships between nitrogen by chemical analysis and sum of internal friction peaks*

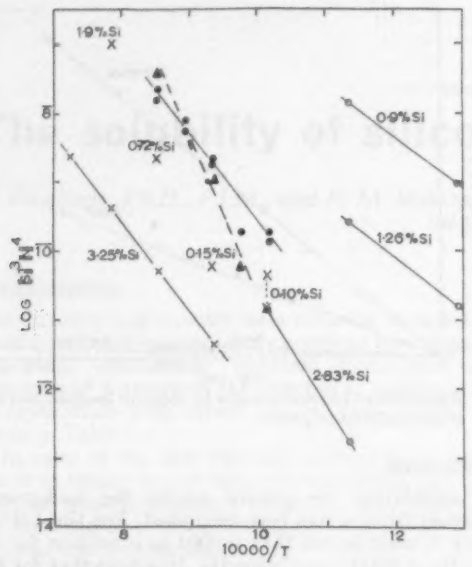
DISCUSSION

In calculating the present results the background internal friction has been neglected. For the 1·9%Si alloy it must be less than 0·0004 as is evident for the results at 700°C (*see* Table II). It is true that for the alloys with less silicon it will be higher and may be as high as 0·002 in the iron–silicon alloys with no nitrogen.[9] In the presence of nitrogen it is impossible to measure accurately but it is believed that the effect of nitrogen is the same as that of silicon, namely to lower the background damping. The effect of this error is that the lines for the 0·5% and the 1·1%Si alloys plotted in Fig.2 should be steeper, the results at the lower temperatures being affected more than those at the higher temperatures. For the 1·9%Si alloy the error from this source is negligible. If one takes a background damping of 0·001 for the 0·5%Si and the 1·1%Si alloys then ΔH works out at about 15·8 kcal/g atom of nitrogen so that the error from lack of knowledge of the background damping is only about 1 or 2 kcal/gmol.

Doubts may be expressed as to the accuracy of the chemical analysis used in correlating the internal friction with nitrogen content. In the alloys used for this correlation there was no visible precipitate of silicon nitride. However, assuming there were some, then if it failed to dissolve in the HCl and HF only the nitrogen in solid solution was determined, which is the figure required. If, however, it did dissolve then this would have shown up by causing scatter in Fig.2 at the high nitrogen end of the plots. There is some, but compared with the overall results it is not important. It is unlikely that silicon nitride would be present in the low nitrogen range except perhaps for the 1·9%Si alloy. If there were some in the latter, then the unexpectedly low figure of 0·05 for k (in the equation $\%N = k\Sigma$ log

TABLE II Solubility results by internal friction

Temp., °C	0·5%Si Total N, % 1	2	0·5%Si N, %, in solution calculated from internal friction	1·1%Si	1·9%Si
600	0·0203	0·0180	0·0030	...	...
700	0·0201	0·0178	0·0061	0·0032	(0·0004)
750	0·0210	0·0200	0·0062	...	0·0017
800	0·0302	0·0285	0·0109	0·0063	0·0036
850	0·0263	0·0250	0·0159	0·0079	...
900	0·0251	0·0224	0·0186	0·0113	0·0086



⊙ Turkdogan and Ignatowicz[3]
× Fryxell *et al*[4]
× Rawlings (metallography and gas–metal equilibrium—unpublished)
◐ ○ ▲ Present work, ◐ 0·5%Si, ○ 1·1%Si, ▲ 1·9%Si

3 *Plots of log* $K = log\ [Si]^3[N]^4$ *against* 1/T

dec.) is high, which seems absurd. There seems no reason to think that the method of analysis is the source of any real error.

Leslie[10] has reanalysed some of the specimens used by Fryxell *et al.*[4] and has come to the conclusion that the results for nitrogen in solution given by Fryxell are low by a factor of 2. If this is true then the line representing Fryxell's results in Fig.3 must be moved vertically by 1·2 units on the log scale, i.e. much nearer the present results.

Leslie[1] has calculated the solubility of silicon nitride in ferrite, the figures so derived for $[Si]^3[N]^4$ being several times lower than the present (and other) results. There are several sources of error in the calculation. Later more accurate results are now available for the free energy of formation of silicon nitride from silicon and nitrogen gas but use of these does not significantly change the calculation. The figures for the solubility of nitrogen in silicon iron used by Leslie may be criticized but the error is not large compared with the divergence between the calculated and the experimental results. The greatest error introduced into the calculation is that involved in the value for the activity of silicon in ferrite. Leslie quotes a result by Gurry (unpublished work) which gives a figure of 3×10^{-5} for the activity coefficient at 900°C. Seybolt[11] has since measured the activity by determining the pressure of nitrogen in equilibrium with ferrite and silicon nitride and comparing it with that in equilibrium with silicon and silicon nitride. He found that at 900°C the activity coefficient of an alloy containing 3·3%Si was $2{\cdot}73 \times 10^{-6}$ and by extrapolation of Chipman's results for the liquid a comparable figure of $2{\cdot}12 \times 10^{-6}$. These much lower figures for the activity coefficient bring the calculated solubility of silicon nitride much closer to the present results.

Until these new results for the activity of silicon are confirmed it is not worthwhile revising Leslie's calculation. As an example, however, the activity coefficient will be obtained from the present solubility results and compared with the available measured results.

For the reaction

$$3Si + 2N_2 = Si_3N_4$$

Pehlke and Elliott[12] give

$$\Delta G = -177\,000 - 5{\cdot}67\ T \log T + 96{\cdot}3T \pm 6000\ \text{cal/g mol}$$

in the range 298–1413°C.

For the reaction

$$\tfrac{1}{2}N_2 = [N]$$

it is preferable to use the results for pure iron since those for silicon iron are in some doubt. For instance, whereas Rawlings[13] found that silicon made the heat of solution more negative, Corney and Turkdogan[14] found that silicon made it less negative. Both found that silicon decreased the solubility but the error involved in neglecting this and using instead the solubility of nitrogen in pure iron is small compared with other unknowns in the calculation. For pure iron at 1 atm N_2[15]

$$\log [N] = -1590/T - 1{\cdot}02$$

Taking $\log [Si]^3[N]^4 = \bar{8}{\cdot}3$ at 900°C from the present work the activity coefficient of silicon referred to solid silicon emerges as $1{\cdot}31 + 10^{-6}$. This agrees very well with that determined by Pehlke and Elliott but at lower temperatures the values from the present results are lower than theirs.

CONCLUSIONS

1. The solubility of Si_3N_4 has been determined in the range 700–900°C using internal friction. The results are given in Fig.3.
2. The activity coefficient of silicon in ferrite calculated from the present results supports the measurements of Pehlke and Elliott rather than those of Gurry.
3. The heat of solution of silicon nitride in ferrite containing 0·5%Si or 1·1%Si was found to be 14·7 kcal/g atom nitrogen, whereas for ferrite containing 1·9%Si the result was 28 kcal/g atom nitrogen. The latter figure is, however, not so reliable because of the low nitrogen contents involved.

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The application of a digital computer to the pre-operational problems of programming the extraction and supply of iron ore

H. I. A. Archibald, B.Sc.(Econ.)

SYNOPSIS

This paper describes the use of a LEO II computer for the daily planning of ore production from quarries supplying the blast-furnaces at Corby, Northamptonshire. The ore varies widely in chemical analysis within each quarry and from one quarry to another, and limits are imposed on the production of each quarry. The computer, which is instructed to produce a result which will give a 'mixture' of a given chemical composition, provides up to ten digging programmes each week. The approach to the problem is re-assessed and possible future developments are discussed. 1949

INTRODUCTION

IN APRIL 1958 a LEO II digital computer was installed at the Corby works of Stewarts and Lloyds Ltd. The work then available for immediate transfer to the computer and the projects being planned for it were largely of the business data processing type. LEO II is built primarily for that type of work. It has a mercury delay line store of 2048 words and on input and output three simultaneously operating channels each with an associated buffer store. Input is by punched paper tape and 80-column punched cards. The output media are punched cards and a 100-lines/min printer.

Part of the Corby payroll had already been regularly processed by LEO Computers Ltd, on a service basis, and it was available for immediate transfer to our own LEO after installation. Soon afterwards the transfer of the remaining works' payrolls to the computer began. This was followed by the application of LEO to warehouse invoicing and associated sales statistics and to general stores accounting and control.

In this atmosphere of business data processing one project of an entirely different nature was being developed. It had begun as a suggestion by Stewarts and Lloyds Minerals Ltd that the computer might be able to assist in the preparation of digging instructions for their ironstone quarries in the Corby area. Although calculation was necessary in the job, it was regarded as supplementary to experience and judgment in the assessment of digging quotas. The challenge in providing a computer system was to translate these qualities or substitutes for them into the numerical terms in which the machine worked. Implicit in the initial suggestion was the idea that the computer might carry out only those parts of the job which were purely arithmetical, such as averaging the chemical analyses of ore samples, but a plan was evolved to use the computer to control the production of ironstone from the quarries supplying the Corby blast-furnaces. What has emerged, and is now running operationally, is a system in which the computer is given the essential information about the quarries available for production, the ironstone ready for extraction in these quarries, and the tonnage of ore required. These data enable the computer to produce a digging instruction showing the quantities of ironstone to be produced from each quarry and the overall average chemical analysis of the total load to be delivered to the blast-furnaces.

Most of the ironstone supplied to the Corby blast-furnaces is extracted in ten quarries situated within a few miles of the plant. Northampton sand ironstone is a low grade ore with an average iron content of 28–30%, and its blending is made difficult by the fact that the chemical analysis can vary widely from one quarry to another and even over short distances within a quarry. In the Corby area it is extracted entirely by opencast methods.

The ironstone bed is laid down in a near horizontal position and is worked at depths varying from a few feet below the surface to over 100 ft, the overburden being removed at each quarry either by a shovel or dragline excavator to form a long trench in the ground. A railway track is laid along one side of the trench and the bed of ironstone is marked off into 22-yd sections. From each section samples of the iron ore are obtained by drilling and these are forwarded to the laboratory for chemical analysis. The results provide the necessary information for forward programming. After the ironstone has been fragmented by blasting, it is extracted by a loading shovel which follows the line of the trench and loads the ore into waiting railway trucks for transportation to the Corby blast-furnace plant. There the ore is crushed and laid out onto beds. On reclamation the ore is screened, and 60–75% is separated and sent for sintering, the remainder being directed to the blast-furnace bins. These processes together with average weekly output tonnages are set out in Fig.1.

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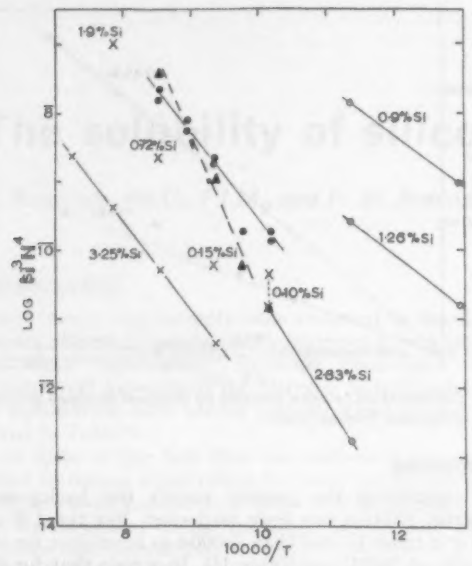
The author is with Stewarts and Lloyds Ltd, Corby, Northants.



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The application of a digital computer to the pre-operational problems of programming the extraction and supply of iron ore

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SYNOPSIS

This paper describes the use of a LEO II computer for the daily planning of ore production from quarries supplying the blast-furnaces at Corby, Northamptonshire. The ore varies widely in chemical analysis within each quarry and from one quarry to another, and limits are imposed on the production of each quarry. The computer, which is instructed to produce a result which will give a 'mixture' of a given chemical composition, provides up to ten digging programmes each week. The approach to the problem is re-assessed and possible future developments are discussed. 1949

INTRODUCTION

IN APRIL 1958 a LEO II digital computer was installed at the Corby works of Stewarts and Lloyds Ltd. The work then available for immediate transfer to the computer and the projects being planned for it were largely of the business data processing type. LEO II is built primarily for that type of work. It has a mercury delay line store of 2048 words and on input and output three simultaneously operating channels each with an associated buffer store. Input is by punched paper tape and 80-column punched cards. The output media are punched cards and a 100-lines/min printer.

Part of the Corby payroll had already been regularly processed by LEO Computers Ltd, on a service basis, and it was available for immediate transfer to our own LEO after installation. Soon afterwards the transfer of the remaining works' payrolls to the computer began. This was followed by the application of LEO to warehouse invoicing and associated sales statistics and to general stores accounting and control.

In this atmosphere of business data processing one project of an entirely different nature was being developed. It had begun as a suggestion by Stewarts and Lloyds Minerals Ltd that the computer might be able to assist in the preparation of digging instructions for their ironstone quarries in the Corby area. Although calculation was necessary in the job, it was regarded as supplementary to experience and judgment in the assessment of digging quotas. The challenge in providing a computer system was to translate these qualities or substitutes for them into the numerical terms in which the machine worked. Implicit in the initial suggestion was the idea that the computer might carry out only those parts of the job which were purely arithmetical, such as averaging the chemical analyses of ore samples, but a plan was evolved to use the computer to control the production of ironstone from the quarries supplying the Corby blast-furnaces. What has emerged, and is now running operationally, is a system in which the computer is given the essential information about the quarries available for production, the ironstone ready for extraction in these quarries, and the tonnage of ore required. These data enable the computer to produce a digging instruction showing the quantities of ironstone to be produced from each quarry and the overall average chemical analysis of the total load to be delivered to the blast-furnaces.

Most of the ironstone supplied to the Corby blast-furnaces is extracted in ten quarries situated within a few miles of the plant. Northampton sand ironstone is a low grade ore with an average iron content of 28–30%, and its blending is made difficult by the fact that the chemical analysis can vary widely from one quarry to another and even over short distances within a quarry. In the Corby area it is extracted entirely by opencast methods.

The ironstone bed is laid down in a near horizontal position and is worked at depths varying from a few feet below the surface to over 100 ft, the overburden being removed at each quarry either by a shovel or dragline excavator to form a long trench in the ground. A railway track is laid along one side of the trench and the bed of ironstone is marked off into 22-yd sections. From each section samples of the iron ore are obtained by drilling and these are forwarded to the laboratory for chemical analysis. The results provide the necessary information for forward programming. After the ironstone has been fragmented by blasting, it is extracted by a loading shovel which follows the line of the trench and loads the ore into waiting railway trucks for transportation to the Corby blast-furnace plant. There the ore is crushed and laid out onto beds. On reclamation the ore is screened, and 60–75% is separated and sent for sintering, the remainder being directed to the blast-furnace bins. These processes together with average weekly output tonnages are set out in Fig.1.

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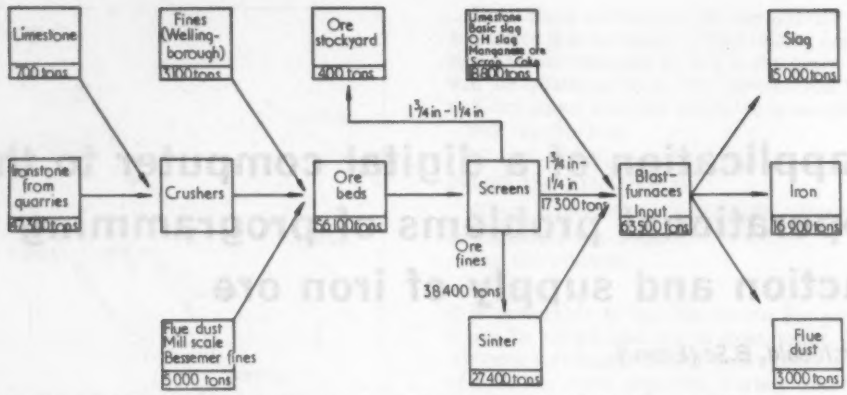

Tonnages shown are weekly inputs and outputs averaged over six months and rounded to the nearer 100 tons

1 *Ore preparation*

The average weekly quarry production for the Corby plant is about 47 000 tons, which is normally divided into eight, nine, or ten crushing and bedding loads called 'mixtures'. All quarries in production dig for the same mixture simultaneously, and all the wagon-loads making up a mixture are crushed and bedded together. The chemical analysis of each mixture must lie within limits specified for each critical constituent by the blast-furnace management. Because of the variations in chemical composition, the required average analysis can be secured only by careful planning of the digging of each mixture. It is not enough to plan a mixture which has an acceptable chemical analysis. It is also important that the tonnage of ore called for from each quarry should be as close as possible to its optimum production.

Previously the task of determining the sequence of quarry operations and of providing digging instructions was performed manually using a desk calculator and charts showing the positions of the baring and loading machines and the ore available in each quarry. The planner allocated the tonnage called for by the blast-furnaces among the quarries in such a way as he thought would provide a mixture with results lying within the specified limits. If, on calculation, it was found that this had not been achieved, the loads were re-allocated until the requirements were satisfied. The digging instruction for the next mixture, showing the quotas called for from each quarry and the resulting average chemical analysis, was then issued. A full description of the ore production process was given in 1950.*

THE COMPUTER SYSTEM

The main reasons for using the computer were to enable mixtures to be produced which would satisfy more regularly and more closely the chemical analysis requirements of the blast-furnace management and to improve the use of quarrying capacity. In addition, because the speed of the computer would mean that a much shorter time would be needed to prepare the digging instructions, forecasts of the starting positions in the quarries for the next mixture, which were a source of inaccuracy, could be made later and with greater certainty than before. Also, it was hoped that short run variations in the chemical analyses of mixtures could be reduced and that provisional forecasts could be made in advance for mixtures which would be required in the following few days.

Of prime importance in the early stages of planning was the need to establish criteria by which the computer could measure the adequacy of any digging instruction on which it was working. This meant that rules had to be drawn up so that the computer could distinguish between a good instruction and a bad one from the point of view of both the chemical analysis of the mixture and the distribution of the required tonnage among the quarries. One such criterion is minimum cost. Subject to any necessary restrictions and management policies this is probably the best guiding rule but the accurate assessment of detailed blast-furnace and quarrying costs would have been a very lengthy task and one which was not then practicable. There was thus no common yardstick whereby deteriorations or improvements in chemical analysis could be measured against better or worse distributions.

It was possible, however, for the managements concerned to set down an ideal value and a tolerance for each critical ironstone constituent, and an optimum, a maximum, and a minimum production for each quarry. It was apparent that a good mixture would be obtained where the average chemical analysis and the digging quotas approximated closely to the constituent ideals and quarry optima respectively. The larger the differences between the actual results and the ideal analyses and productions, the less acceptable the instruction would become. On this basis it was possible to construct an 'acceptability index' which would take into account the differences between the ideal analyses and productions and the actual levels of these existing at any point in the computer process. The index would be large when a poor distribution, in terms of analysis and quarry productions, had been obtained and would progressively diminish as the results approached the ideals.

It would have been futile, of course, to have included such dissimilar terms in the index with no indication of their relative importance. Provision was made, therefore, for weightings to be applied to each constituent and quarry term. Since it was impossible to

* J. R. Menzies-Wilson: Presidential Address, *JISI*, 1950, **165**, 129–137.

TABLE I Digging instruction

1. VARIABLE DATA

Tonnage required 5780 tons

Limestone

Tonnage	Iron, %	Sulphur, %	Silica, %	Lime, %
80	1·00	0·11	0·6	52·5

Ironstone

Quarry	Section	Tonnage available	Iron, %	Sulphur, %	Ferrous iron, %	Silica/lime ratio	Iron/silica + lime ratio
Cowthick	48	460	28·0	0·30	14·0	0·75	1·52
	47	1940	29·9	0·31	10·3	1·28	1·62
Priors Hall	85	2280	25·3	0·43	17·2	0·82	1·30
Earlstrees	98	1600	27·8	0·53	21·4	0·66	1·58
Brookfield	212	480	29·3	0·22	8·0	0·90	1·75
Cottage	213	1880	31·7	0·26	7·4	2·00	2·30
Park Lodge	86	500	30·9	0·07	0·8	0·83	1·82
	87	700	31·0	0·07	0·5	0·95	1·69
Park Lodge	68	400	28·8	0·58	15·9	1·80	1·91
North	69	1120	30·0	0·47	17·6	2·90	2·48
Martins	4	1060	27·4	0·42	24·0	1·10	1·89
Rothwell West	Fixed load	320	32·6	0·06	1·6	1·70	2·19

2. RESULT

Average chemical analysis of mixture, %

	Result	Ideal	Tolerance
Iron	28·200	...	...
Sulphur	0·343	0·340	±0·06
Ferrous iron	13·6	14·0	±3·0
Silica/lime ratio	0·90	0·90	±0·01
Iron/silica + lime ratio	1·64	1·70	±0·075

Digging quotas

	Tons	20-ton wagon loads	Quarry ideal production (in 20-ton wagon loads)
Fixed loads Limestone	80	4	...
Rothwell West	320	16	...
Cowthick	680	34	36
Priors Hall	960	48	52
Earlstrees	900	45	42
Brookfield Cottage	960	48	48
Park Lodge	660	33	32
Park Lodge North	480	24	27
Martins	740	37	32
Total	5780		

evaluate these weightings in any other way, they had to be assessed by trial and error using the computer itself. This was achieved by carrying out a series of experiments, using actual situations, designed to discover levels for weighting which would create the appropriate balance in the index between the chemical analysis and the quarry productions. The experiments were carried out by making one alteration to the weightings before each run on the computer and observing the effect on the results produced. After a few runs it was found that the effect of these single alterations could be fairly accurately forecast and it became possible to take short cuts which considerably reduced the experimental time required on the computer.

When apparently satisfactory weightings were available, a number of runs were carried out on 'live' data and the results were scrutinized by minerals company officials. The main criticism made by them was that although the computer was producing results in which all the constituents were very close to their ideals, this seemed to be at the expense of the digging quotas which were unsatisfactory. It was clear that the index was not yet correctly balanced. This was remedied by carefully scaling up the quarry weightings and carrying out further experiments on 'live' data until the digging instructions produced were satisfactory. All quarries were weighted equally as there was no accurate evidence available to substantiate any variations.

For up to ten mixtures a week the computer provides a digging instruction showing the number of 20-ton wagon-loads to be dug from each quarry towards the next mixture, and the resultant average chemical analysis. The more permanent information, such as weightings and quarry and constituent limits and ideals, is contained in the programme of instructions which is fed into the computer at the beginning of each run. Variable information, such as the total tonnage required, and the section details for quarries available for production is read in afresh for each run even although some of it may not have altered. In addition the tonnage and chemical analyses of any loads of limestone or of iron ore from quarries outside the Corby area are also submitted as current data.

The total tonnage required is allocated to the available quarries in proportion to their ideal productions, each quota being expressed as a number of 20-ton wagon-loads. The object of further operations is to redistribute the loads among the quarries in a way that will provide a low value for the acceptability index. First a wagon-load is moved from quarry 1 to quarry 2. If this results in a raising of the index the transfer is cancelled. If the index falls the transfer is completed and further exchanges are made between these quarries until a further transfer would raise the index. The computer then attempts transfers between quarries 1 and 3 and so on until transfers have been tried between quarry 1 and every other quarry available for production. Exchanges are then tried between quarry 2 and all the others, this procedure continuing until all combinations have been tried twice. A result is then printed. Table I shows a typical set of data and the result produced by the computer.

A second result is then produced using an experimental improvement routine. This scans the first

result, closes any quarries where the quota is below a certain minimum tonnage, and re-allocates their loads to the quarries remaining open. If necessary, quarry weightings are marginally adjusted before a further two cycles of exchanges are carried out and a second and final result is printed.

All communications between the computer centre and the minerals company are by telephone. The average duration of the complete process from the receipt of data until the result is in the hands of the minerals company is about 1 h. Of this, the computer run takes 20 min, the remaining time being spent in data preparation and waiting for a suitable opportunity to put the job on the machine.

REASSESSMENT AND POSSIBLE FUTURE DEVELOPMENT

The system initially devised and programmed was designed to embrace not only the central task of preparing digging instructions but also several other aspects of the control of ironstone production. These ancillary tasks required programme routines which, to give examples, maintained the section details file, rejected sections, and accumulated statistics. Some of these operations were complex in themselves and they distracted attention from the central object of the job. It is now clear that these peripheral tasks should either have been excluded entirely from the scope of the programmes, or, if their inclusion had been advantageous, have been left until the main problem had been solved. In fact, all the operations quoted were eventually removed from the programmes.

The fulfilment of the project was also inhibited by the imposition of some unnecessary restrictions. The improvement effect of the load-exchanging routine was hampered because exchanges could take place only between quarries using the same size of wagon. Moreover, because the computer run was to take place daily, loads could be exchanged only within that part of a mixture which was to be dug within one day. These restrictions were overcome by assuming all wagons to be of 20 tons capacity, making the necessary conversions after the computer result was produced, and by running the job on the computer mixture by mixture, providing a result for a complete mixture irrespective of whether it was to be dug on one day or two.

One of the most important conclusions arising from this project is that a clear distinction must be made, at as early a stage as possible, between tasks which are essential and worth while, and those which are merely feasible. Feasibility, by itself, is not a satisfactory reason for including ancillary routines in a computer programme.

When it was begun in 1957 this was an ambitious project and one for which there was no related experience. What has resulted is a system which can regularly and reliably provide acceptable digging instructions and which has shown that, to some extent at least, it is possible to translate human judgment and experience into a computer programme.

Future developments of this project are likely to fall under two heads:

(i) an attempt to eliminate short-run fluctuations in the chemical analysis of mixtures
(ii) a reassessment of the problem with a view to providing an optimum solution for a mixture or a consecutive series of mixtures using some measure of effectiveness, such as costs.

The first of these developments would involve the reintroduction to the system of routines which were present in the original set of programmes but which were eliminated during a phase of simplification. Mixture-to-mixture fluctuations can be controlled only by taking account of the analyses and tonnages of ironstone in sections additional to those which are likely to be worked to produce ironstone for the first mixture of a series. Subject to the regular availability of this information, it would be possible to provide, in addition to a digging instruction, forecasts for several mixtures ahead, at the same time making an attempt to keep their chemical analyses within predetermined ranges.

The other possible development would be considerably more radical in its effect. It is clear, however, that no economic solution will be possible without a rigorous re-examination of the problem aimed at uncovering the policies and facts which should guide and restrain the short-run tactics of blast-furnace and quarry operation.

ACKNOWLEDGMENTS

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Sinter plant assessment trials at Guest, Keen Iron and Steel Co. Ltd

J. McKelvie, B.Sc., and G. Wilson

SYNOPSIS

A trial has been carried out to assess the performance of the sinter plant at the Cardiff works of Guest, Keen Iron and Steel Co. Ltd. The processing of the entire feed to the sinter strand by a drum pelletizer was found to improve the size grading of the raw mix and thus the bed permeability. The leakage of air between the strand and the fan was measured and was found to be lower than that obtained during other BISRA assessment trials, being only 32% of the total fan air flow. 1938

INTRODUCTION

FOLLOWING A SERIES of previous trials at various plants, BISRA made arrangements to carry out tests at the sinter plant of the Guest, Keen Iron and Steel Co. Ltd. One distinctive feature of this plant is the pelletizing drum through which the sinter mix is passed immediately before being fed to the strand. During the trial the plant was operated normally and the same ore mix was used throughout the period. The trials team had the full co-operation of the management and the operators, and also had much helpful advice and the loan of equipment from the company's research department.

DESCRIPTION OF THE PLANT

Sinter machine

The sinter plant is a single continuous strand built by Lurgi G.m.b.H. and came into operation in June 1958. The layout of the plant is shown diagrammatically in Fig.1. The strand is 2 m (6 ft 6¾ in) wide with an effective length of 30 m (98 ft 5 in) divided into 16 windboxes. S-type[5] dust catchers are installed between each of the first ten windboxes and the windmain, while the last six windboxes are connected to 'multiturb'[5] dust catchers. Each windbox is fitted with a slide valve normally used only when starting up the plant, but the valves on the first two windboxes were not fully opened while operating. There are 81 pallets, each 1 m long: at the discharge end of the strand, pallets are carried round by a large double sprocket and do not impact on the pallet ahead. During the trial the bed height was maintained at 15 in. The fan is of the backward bladed type, the design rating being 160000 ft³/min at 300°F and at 36 in wg suction. The fan runs at constant speed (970 rev/min) control being by vanes. Before the fan a final dust catcher known as a 'policeman' is fitted.

After passing through the sinter breaker, material is screened hot on a perforated plate screen (⅜ in × ⅜ in perforations), oversize material being fed to a rotary cooler of the Lurgi-Frodingham type. The undersize is conveyed by vibra-conveyor and tray conveyor to the returns bin from which it is returned to the sinter mix via the primary mixer. Sinter from the cooler is conveyed to screens in the sinter bunker building where the hearth layer (between ⅝ in and 1 in) is screened out. The sinter is held in two bunkers, having a combined capacity of 300 tons, which are emptied periodically, the finished sinter being transported to the blast-furnaces by belt conveyor. Provision is made to by-pass the sinter screens if necessary (*see* Fig.1). Three 'Adequate' belt weighers are installed; one on conveyor M1 gives the weight of ores, flue dust, and coke; another on conveyor M2 situated after the primary mixer, also includes return fines; a third belt weigher on conveyor S5 gives the weight of finished sinter sent to the blast furnaces.

Raw materials

The sinter plant stockyard is adjacent to the feeder table bunkers and a flexible system of raw material supply is in operation. Ore may be screened on the plant at ⅜ in and the fines discharged directly by tripper car to the feeder table bunkers or to the sinter plant stockyard. Imported ore fines and flue dust can also be fed directly to the feeder table bunkers or to the stockyard. Home ore (Oxfordshire) is screened at 2 in square mesh and then dried and hammer milled smaller than ⅜ in for sintering. Material is transferred from the stockyard to the feeder table bunkers by grab crane.

Coke breeze is screened at ⅛ in on a Moxey-Dillan screen 14 ft × 5 ft with ⅛ in × 1 in mats and gas heating. Oversize material is stored in a bunker from where it is discharged by a rotating table, fed to the rod mills and crushed smaller than ⅛ in. Crushed coke and undersize from the screen both feed via a common

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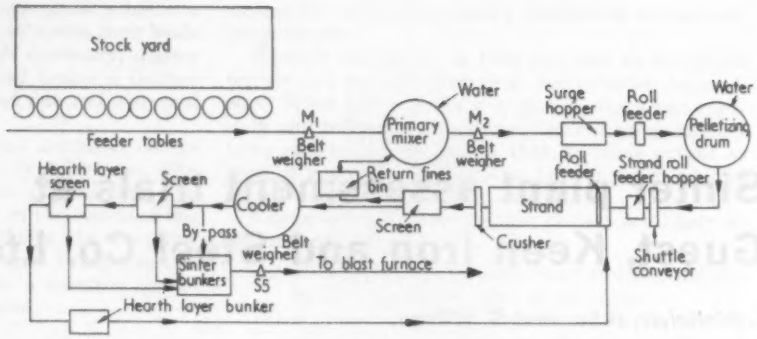
The authors were members of the staff at BISRA's North-East Coast Laboratory, Normanby, Middlesbrough, when this paper was written.



1 *Diagrammatic layout of sinter plant*

conveying system to either of two coke feeder bunkers or to the stockyard.

Mixing and feeding

There are nine bunkers for ores and flue dust and two coke bunkers. Discharge from the ore bunkers is by rotating tables, the coke bunkers being fitted with constant weight feeders. The speed of all the feeder tables can be varied simultaneously from the strand control room, individual adjustments being made by adjusting the plough setting. The components of the mix are checked regularly by the operators who pass a tray of standard length under a given feed table and weigh the amount of material collected on scales graduated to give a reading directly in tons per hour. An 'Adequate' belt weigher indicates the flow rates and gives an integrated reading of the total weight of materials from the feeder tables; ore, flue dust, and coke. These materials are then conveyed to the primary mixer where return fines are added from the bin situated above. Part of the necessary water addition is made in the primary mixer. From the primary mixer the mix is conveyed to a surge hopper and from there to the pelletizing drum. A belt weigher is installed to give the weight of material from the primary mixer.

The pelletizing drum is 23 ft long and 9 ft 8 in internal diameter, with weir plates fitted around the circumference at the discharge end: during the first two days of the trial the plates extended $15\frac{3}{4}$ in from the inside of the drum but for the last two days $13\frac{3}{4}$ in plates were used. The drum is driven by a dc variable-speed motor of 120 hp, which has replaced the original motor, and gave a drum speed of 7 rev/min during the trial. The final water addition is made in the drum by sprays placed near the feed end of the drum. On discharge from the drum, the mix feeds onto a shuttling conveyor which spreads the mix evenly into a small hopper above the roll feeder.

Plant instrumentation

All control switches for stopping and starting the strand, conveyor belts, feeder tables, etc., are situated in a control cabin on the strand floor together with the plant instruments listed below:

(i) the feed rates of material both into and from the primary mixer are indicated in tons/h
(ii) strand speed is indicated in in/min
(iii) feeder table speeds are indicated in rev/min
(iv) the setting of the constant weight coke feeder is indicated in tons/h
(v) the pelletizing drum speed is indicated in rev/min
(vi) the weight of materials in the surge bin is indicated
(vii) the rate of water addition in both the primary mixer and pelletizing drum are indicated in gal/min
(viii) fan suction is indicated and recorded; suctions at nos.2 and 9 windboxes are indicated and the suction at no.9 is also recorded and known as strand suction
(ix) the temperatures at windboxes 4, 6, 8, 10, and 12–16 are indicated and also the fan inlet temperature; the temperatures at windboxes 13, 14, 15, and 16 and at the fan inlet are also recorded
(x) sinter fan vane position is indicated
(xi) the current consumptions of the sinter fan motor, the strand motor, and the pelletizing drum motor are indicated in amperes.

Trial conditions and measurements

The ore mix was nominally constant during the trial period and the plant was operated normally. In the 8-h assessment periods chosen, therefore, no major variations in operating conditions occurred, while short term random fluctuations had a negligible effect.

The proportions and feed rates of the different ores and flue dust were determined by tray weighings. Cumulative samples of ores, flue dust, and coke were collected and used for size and chemical analyses. Readings were taken of the integrated weights shown by the belt weighers before and after the primary mixer at the start and finish of each day's trial and at hourly intervals throughout. The size analysis of the mix before and after the pelletizing drum was also determined frequently. Samples of raw mix were also taken just before the strand cut-off plate and used to determine size segregation and carbon segregation. The moisture contents of the raw mix and the coke were determined.

The weights recorded on the belt weigher for finished sinter were noted at the start and finish of each day's trial and the sinter bunker discharge was arranged so that the bunkers were empty at both these times. A large sample of finished sinter was collected on one day after the cooler and size and chemical analyses carried out. In addition a number of samples of sinter from the cooler were taken and the temperature of each one determined with a calorimeter. The pressure drop across the 'policeman' was

TABLE I Average conditions observed during trial

Date	2.9.59	3.9.59	4.9.59	5.9.59
Time	9.30–5.15	9.30–5.00	9.20–5.40	9.30–12.30
Bulk density of raw sinter mix, lb/ft³	...	119·4	121·9	...
Bed height, in, including 1 in hearth layer	15	15	15	15
Strand speed, in/min	74	78·7	78	78
Raw mix to strand, tons/h	130·6	135·6	135·4	143·8
Ignition gases, ft³/min				
Blast-furnace gas	1895	1900	1895	1910
Coke-oven gas	135	123	125	127
Average strand suction, in wg	31·1	32·8	31·5	33·1
Average fan inlet suction, in wg	44·1	41·1	40·2	41·5
Average fan inlet temp., °C	132	145	150	144
Average fan volume, ft³/min, NTP	72000	78700	80000	77600
Average leakage airflow, ft³/min, NTP	25750	24700	24100	24800
Average bed waste gas volume, ft³/min	46250	54000	55900	52800
Average fan volume/ton raw mix, ft³/ton	33150	34850	35400	32400
Calculated average bed permeability, BPU	46·2	52·1	55·4	50·8
Calculated 'bed/air' ft³/ton raw mix	21250	23900	24800	22100
Moisture in raw mix, %	9·9	9·9	9·72	...

used to deduce gas volumes at the fan, and readings of airflow through the sinter bed were taken using a vane anemometer.

EXPERIMENTAL PROCEDURE

Measurement of gas flow

Pressure tappings were inserted before and after the 'policeman', and the pressure drop across it, and also the suction and temperature after it, were noted every 20 min during the trial periods. The pressure drop was calibrated against gas volume flowing by means of a pitot traverse in the main after the 'policeman'. Temperatures and suctions at several windboxes were obtained from the plant instruments.

Mix composition and input to the strand

Hourly readings of the feed rate from each feeder table were obtained; a tray was placed on the gathering belt and after it had passed under the appropriate table the material collected was weighed. Three tray passes were made at each table and the average value taken. At each of the three passes the tray was placed on the belt so that material was collected from a different 120° segment of the table. The importance of such a sampling procedure has been previously stressed.[4] Hourly readings were also taken of the integrated reading on the belt weighers before and after the primary mixer. Samples of the mix were taken immediately before and after the drum pelletizer and size analyses were carried out.

Strand speed

The strand speed in inches per minute was indicated in the control cabin. The reading given was checked by stop-watch and found to be correct.

Table II Standard ore mix and daily average composition, %

	Standard	2.9.59	3.9.59	4.9.59
Labrador A	26·9	24·0	25·0	22·6
Purple ore	11·2	12·1	11·7	10·9
Ouenza	13·4	13·5	12·4	11·5
Llanharry	5·6	9·6	7·5	10·9
Granada	14·7	16·2	18·0	23·0
Concentrates	11·2	10·6	11·2	9·3
Oxford	17·0	14·0	14·2	11·8

TABLE III Average material input rates, dry mix, tons/h

	2.9.59	3.9.59	4.9.59	5.9.59
Return fines	39·3	35·4	37·0	41·1
Coke	5·5	4·8	4·9	5·1
Flue dust	9·3	7·5	7·1	85·3
Ores	63·6	74·5	73·2	...
Total	117·7	122·2	122·2	131·5

Segregation of raw mix on the strand

A sampling device was used to take samples of the raw mix simultaneously from three levels. The samples were then sieved at $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, and $\frac{1}{16}$ in and selected samples were analysed for carbon content.

Moisture content

The moisture content of the coke was determined hourly by a 'Speedy' moisture tester. Two samples of coke daily were used for moisture determination by oven drying. Four samples of raw mix were taken daily and the moisture content determined by oven drying.

OBSERVATIONS AND RESULTS

The average conditions observed during the trial are shown in Table I. The derived data have been calculated from the following basic equations.

$$\text{Specific waste gas volume } V = \frac{60F}{I} \text{ ft}^3 \text{ at NTP}$$

$$\text{Permeability } P = \frac{F}{A}\left(\frac{h}{s}\right)^{0.6}$$

where F = waste gas flow, ft³/min at 60°F and 30 in Hg; A = area of strand, ft²; I = material input rate, tons/h; h = depth of bed before ignition, in; s = suction, in wg.

Material flow

During the trial the integrated readings of the three belt weighers were noted every hour and tray weighings were taken at the main gathering belts for ores and flue dust. Tray weighings for coke proved impracticable owing to the somewhat intermittent nature of the coke feed onto the belt. This was caused by the moisture in the coke producing on the feeder belt a lightly bonded cake which broke as it reached the edge of the coke feeder belt. Any irregularities in coke content of the mix on the belt due to this are, of course, eliminated in the primary mixer. Coke rates have therefore been taken directly from the coke weigher feeder indicator. Table II shows the standard mix composition together with the average daily mix as determined by tray weighings at the feeder tables, and

TABLE IV Change in mix size distribution before and after the pelletizer

	3.9.59			4.9.59		
Fraction, in	% before	% after	Ratio, after/before	% before	% after	Ratio, after/before
$+\frac{1}{2}$	0·4	1·2	3·3	0·4	0·3	0·8
$-\frac{1}{2}+\frac{1}{4}$	14·8	29·2	1·9	13·5	16·1	1·2
$-\frac{1}{4}+\frac{1}{8}$	31·0	33·9	1·1	29·6	35·6	1·2
$-\frac{1}{8}+\frac{1}{16}$	25·0	18·4	0·7	16·7	20·4	1·2
$-\frac{1}{16}$	28·8	17·3	0·6	39·8	27·6	0·7
Mean size, in	0·081	0·119	1·47	0·058	0·084	1·45
Weir plate, in	...	$15\frac{1}{4}$	...	...	$13\frac{1}{4}$	...

TABLE V Average size analyses for three layers of bed, %

	3.9.59				4.9.59			
Fraction, in	Top	Middle	Bottom	Average	Top	Middle	Bottom	Average
$+\frac{1}{4}$	23·6	47·3	57·6	42·8	32·6	48·1	56·5	45·6
$-\frac{1}{4}+\frac{1}{8}$	36·4	32·4	30·3	33·3	36·2	32·2	28·6	32·4
$-\frac{1}{8}+\frac{1}{16}$	20·5	9·9	5·5	12·0	16·9	9·9	6·9	11·2
$-\frac{1}{16}$	19·5	10·4	6·6	12·2	14·4	9·8	8·0	10·8
	Segregation index +7·0				+6·0			

Table III the average dry material input rates in tons per hour. The chemical and physical analyses of the raw materials and of the finished sinter are shown in the Appendix.

Moisture in the coke, as determined by oven drying, showed an average value of 9·3%, with maximum and minimum values of 13·5% and 6·7% respectively. The moisture in the final mix to the strand was substantially constant at 9·9%. The calibration of the weighing machines for the tray weights and the speed of the main ore gathering belt has been checked by Guest, Keen and found to be accurate.

The drum pelletizer

The function of the drum pelletizer is to alter the size analysis of the mix so as to increase the bed permeability as compared with an unpelletized mix. The size analysis results before and after the pelletizer are shown in Table IV. The proportion of $+\frac{1}{2}$ in material in the mix is so small that it is probable that large errors exist in the percentages quoted for this fraction due to errors in sampling and breakage on the sieve. The $-\frac{1}{16}$ in fraction is also thought to be low because of the inevitable pelletizing which occurs on the sieve when determining this fraction.

With the $15\frac{3}{4}$ in weir plate in use the greatest effect is on the $+\frac{1}{4}$ in fraction while with the $13\frac{3}{4}$ in weir plate the effect appears to be spread evenly over $+\frac{1}{4}$, $+\frac{1}{8}$, and $+\frac{1}{16}$ in fractions. In both cases the reduction in the proportion of $-\frac{1}{16}$ in material is approximately the same. It will be noted, however, that the mean size, calculated as in Ball,[6] increases in the same proportion with either weir plate. It should be pointed out moreover that the size distribution of the mix entering the pelletizer was somewhat different on the two occasions when the different weir plates were in use, and this may account in part for the effects stated.

In order to obtain information on the residence time and the weight of mix in the pelletizer the drum was stopped on two occasions; once when the $13\frac{3}{4}$ in weir plate was in use and again when the $15\frac{3}{4}$ in weir plate was in use. From measurements of the depth of mix and of bulk density on these occasions and from the known rate of input of mix, the apparent residence times were calculated. For the $13\frac{3}{4}$ in weir plate the residence time was 3·6 min and weight of material in the drum was 8·2 tons, while for the $15\frac{3}{4}$ in weir plate 4 min and 9 tons were obtained respectively. It should be noted, however, that caking occurs on the drum wall and therefore the amount of material actively pelletizing was less than that calculated above so that the residence time was probably shorter than stated.

TABLE VI Chemical analysis of segregation samples from strand

	3.9.59			4.9.59		
Position	Top	Middle	Bottom	Top	Middle	Bottom
Total Fe	52·7	52·5	52·4	54·3	54·0	52·0
Ferrous Fe	4·5	4·4	4·6	4·0	4·2	4·1
SiO_2	6·62	8·38	6·72	7·26	7·20	7·47
CaO	4·52	5·78	6·96	4·10	4·68	5·08
CaO/SiO_2	0·68	0·69	1·03	0·57	0·65	0·68
Al_2O_3	1·37	2·59	1·10	1·55	1·84	1·51
MgO	0·63	0·72	0·62	0·53	0·61	0·58
CO_2	2·3	3·1	2·7	2·0	2·5	2·8
Carbon	4·21	3·65	3·03	3·78	3·52	3·20
Equivalent coke	4·54	3·56	2·90	4·10	3·60	3·09
Loss on ignition	7·89	8·72	8·17	7·81	7·77	8·08

Segregation on the strand

The need for a segregated bed has been mentioned in other reports[2] and in continuation of the BISRA policy of measuring segregation in the bed, samples were taken just before the cut-off plate. Owing to the comparative inaccessibility of the sampling position it was only found possible to use a multi-shovel consisting of three sampling scoops. This has made the calculation for the segregation index, calculated as in ref.2, somewhat unreliable. The averages of results obtained are shown in Table V and the segregation index calculated from these results is 7·0 and 6·0 for 3.9.59 and 4.9.59 respectively.

The chemical analysis of the combined samples is shown in Table VI, from which it would appear that there is some evidence of carbon segregation, the segregation indices for the two days being −7·0 and −4·6.

Segregation of the lime-bearing particles of the bed also appears to have taken place. This is probably due to the preferential segregation of the Oxfordshire ore which has a high lime content associated with a coarse size analysis. If a higher average lime/silica ratio were required throughout the bed it would thus seem to be necessary to reduce the particle size of the Oxfordshire ore either by screening or crushing.

IGNITION

The average ignition gas volumes for the assessments are shown in Table VII together with the air volumes supplied. While gas volumes are constant there is some variation in the air supplied, and this produced a slight difference in the air/gas ratio, the average for the trial being 1·25; the theoretical ratio required to give inert ignition is also given in Table VII. The average

TABLE VII Ignition conditions

	2.9.59	3.9.59	4.9.59	5.9.59
Blast-furnace gas, ft^3/min	1895	1900	1895	1910
Coke-oven gas, ft^3/min	135	123	125	127
Air supplied, ft^3/min	2550	2280	2640	2735
Theoretical air, ft^3/min	1940	1890	1900	1890
Air/gas ratio				
Actual	1·25	1·13	1·31	1·34
Theoretical	0·95	0·93	0·93	0·93
Excess air, %	31	21	38·5	44·2
Ignition intensity, Btu/ft^3 min	3670	3600	3620	3640
Total heat input, Btu/ft^3	5840	5400	5450	5500

TABLE VIII Heat requirement and productivity

	2.9.59	3.9.59	4.9.59
Coke, therms/ton sinter	18·18	16·89	17·47
Flue dust, therms/ton sinter	4·12	3·50	3·36
Blast-furnace gas, therms/ton sinter	1·36	1·45	1·44
Coke-oven gas, therms/ton sinter	0·47	0·46	0·47
Total heat input, therms/ton sinter	24·13	22·30	22·74
Coke, %	4·65	3·94	4·02
Return fines, %	33·4	29·0	30·3
Strand speed, in/min	74	78·7	78
Sinter output, tons/h	77·4	73·4	72·4

ignition intensity was 3630 Btu/ft²/min, and the average total heat input per ft² was 5550 Btu, the calorific values of coke-oven gas and blast-furnace gas being 452 and 93 Btu/ft³ respectively. Ignition time varied only slightly, due to varying strand speed, and was about 1½ min. Throughout the trial it was noted that the top of the bed had a smooth appearance and was very well bonded.

Waste gas volume

The total gas volume drawn through the fan is made up of bed waste gas and leakage air. The actual volumes of waste gas passing through the sinter bed have been calculated by allowing for the leakage air into the system. From Table I it may be seen that the fan volume varies from 72000 to 80000 ft³/min, with a corresponding variation in bed waste gas volume of 46250 and 55900 ft³/min. Leakage volumes are of the order of 32% of the total fan volumes. The average bed permeability has been calculated from the average strand suction over the assessment period and the average waste gas volume passing through the bed.

Plant leakage

The method of determining the plant leakage airflow was the same as used on previous plant assessments.[1–3] The cold stationary strand was sealed with strong brown paper and various suctions applied. The total air flowing under these conditions was then calculated from the previously calibrated final dust catcher. On first attempting this procedure it was found that abnormally high suctions were obtained under the strand; in fact sufficient to rupture the brown paper. To overcome this it was found necessary to remove four inspection covers from the fan casing thus reducing the fan suction and bringing the strand suction down to manageable levels.

The results indicate that the leakage airflow is given by $V=4300\,(h)^{\frac{1}{2}}$, where h=strand suction, in wg, and V is in ft³/min.

It will be seen from Table I that values of about 25000 ft³/min, were obtained for the leakage volume which was about 32% of the total airflow at the fan. This is lower than encountered at any previous plant assessed. The low leakage was confirmed to some extent by the high suctions obtained as noted above and was also borne out by inspection of the pallet seals and dust catcher seals when the plant was operating, little leakage being detectable.

Airflow through the strand

The use of an anemometer to indicate the airflow through the strand has been previously reported.[1] At Cardiff a vane anemometer (electrically recording) was used and readings were taken of the airflow at the middle and two sides of the bed on three consecutive runs, during which the anemometer was placed on the sinter bed surface and allowed to travel with the strand. Readings were taken over each windbox from no.6 to no.15. From the results it was apparent that variation in airflow did occur across the bed, the east, middle, and west positions accounting for approximately 37·4%, 30·2%, and 32·4% of the total average flow. It may be considered that this is due to uneven particle size distribution, the centre receiving a less permeable mix than the sides. The general airflow pattern along the strand was consistent with the normal variations associated with the progress of the flame front down the bed.

Fan suction

Table I shows a difference in pressure between the strand and the fan of about 10 in wg. About half of this occurred across the 'policeman', the remainder arising in the collecting main system.

Heat requirements

Table VIII shows the individual heat contributions of the ignition gases, coke, and flue dust per ton of finished sinter together with the output details; the carbon content of the coke has been taken as 79% and the calorific value of carbon as 14593 Btu/lb. Reference to Table VIII shows that the amount of coke used on 2.9.59 was greater than on succeeding days, probably giving a lower return fines make and consequently a higher yield of blast-furnace sinter; in fact calculations showed that the return fines make was less than that required for the raw mix.

Sinter cooling

During one day of the trials samples of sinter were taken from the conveyor belt just after leaving the cooler and the temperature determined with a large calorimeter. Samples were obtained about every 45 min throughout the day, and the lowest temperature recorded was 48°C and the highest 222°C. The average temperature was 136°C.

CONCLUSIONS

The trial has shown that the volume at the fan, per ton of raw mix passing over the strand, varied from 32400 to 35400 ft³ NTP and that the bed 'air' per ton of raw mix varied from 21250 to 24800 ft³ NTP. Measurements of the leakage volume showed a low value and averaged 24800 ft³/min NTP, which was about 32% of the total volume at the fan.

During the trial calculated average bed permeabilities during sintering varied from 46 to 55 Bpu, with a corresponding change in strand speed of 74 in/min to 78 in/min. Moisture variation in the raw mix was low and good control over this variable was apparent: the average moisture in the mix was 9·9%.

The drum pelletizer performs a useful function, the pelletizing effect being mainly on the $-\frac{1}{16}$ in fraction. The use of 15¾ and 13¾ in weir plates appears to influence the residence time, the 15¾ in plate apparently giving a greater yield of larger size pellets.

ACKNOWLEDGMENTS

The authors wish to thank the management of Guest, Keen Iron and Steel Co. Ltd, for permission to carry out the trial, for the help and advice rendered; and also the following for their assistance: Monsieur M. Auxenfans (IRSID), Mr J. R. Rodgers (Steel Company of Wales Ltd), and Mr Dickson (Stewarts and Lloyds Ltd).

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Appendix

A Chemical analysis of materials, %

	Ferrous Fe	Total Fe	SiO_2	CaO	Al_2O_3	MgO	Loss on ignition	C	S
Labrador A	0·20	59·2	9·9	0·26	0·36	0·12	4·46	...	0·027
Purple ore	0·7	62·4	5·53	0·92	1·29	0·44	2·07	...	0·497
Ouenza	0·2	56·6	2·55	3·94	0·63	1·10	7·45	...	0·043
Llanharry	1·1	46·8	7·4	3·66	0·36	0·47	10·92	...	0·023
Granada	0·1	57·0	5·0	3·66	1·27	0·72	6·13	...	0·022
Concentrates	5·9	64·8	5·38	0·38	0·43	0·61	0·74	...	0·022
Oxford	2·2	25·8	10·92	19·06	0·95	1·58	3·96	...	0·022
Flue dust	18·0	46·3	11·16	6·08	0·66	11·38	...	10·52	0·137
Finished sinter	11·8	57·9	8·55	5·22	3·01	0·82	...	...	0·015

B Size analysis of raw materials

	Inches					Mesh					
	$-\frac{1}{2}$	$-\frac{1}{2}+\frac{3}{8}$	$-\frac{3}{8}+\frac{1}{4}$	$-\frac{1}{4}+\frac{1}{8}$	$-\frac{1}{8}+\frac{1}{16}$	$-\frac{1}{16}+30$	−30+40	−40+60	−60+85	−85+100	−100
Labrador A	nil	7·0	10·6	10·6	18·8	34·2	7·1	3·5	3·1	0·5	4·6
Purple ore	nil	nil	nil	17·1	49·5	16·2	3·2	2·5	2·5	1·1	7·9
Ouenza	nil	5·1	7·7	19·3	21·8	15·8	3·9	2·9	3·1	0·9	19·5
Llanharry	nil	8·3	12·4	34·0	41·1		2·2	1·0	0·6	0·1	0·3
Granada	nil	nil	nil	2·3	7·2	32·2	9·2	7·7	10·3	2·3	28·8
Concentrates	nil	nil	nil	nil	nil	15·8	16·3	17·1	22·7	7·9	20·2
Oxford	0·5	5·2	13·3	22·3	15·5	31·8	2·1	1·5	1·9	0·5	4·4
Flue dust	nil	nil	nil	nil	nil	12·6	11·2	15·2	21·2	6·0	33·8
Coke	nil	nil	nil	0·8	14·9	30·7	10·5	7·6	11·6	3·5	20·4

C Size analysis of finished sinter

Size, in	+5	−5+4	−4+3	−3+2	−2+1	−1+½	−½+¼	−¼
%	3·6	1·1	4·5	5·9	13·5	25·4	33·1	12·7
			Strength index (shatter)		56·5			
			Dust index		12·2			

STAL *in English*

Number 12 (December 1960) of the cover-to-cover translation of the Russian journal *Stal'* has been published and no.1 of the 1961 series (January) should appear early next month. Full details of subscriptions to *Stal in English* are available from the Secretary of The Iron and Steel Institute.

Surface effects occurring during the heating and cooling of plain carbon steels*

Professor **P. Bastien** and Monsieur **Colombié** (Centre de Recherches de Physique Ecole Centrale des Arts et Manufactures, Paris) wrote: We have noticed with great interest the important work on the surface effects of carbon steels, reported in this paper, and we should like to congratulate the authors. During a two-year study which we made on the dry corrosion of steel in hot carbon dioxide under pressure, to obtain reproducible results we annealed samples under vacuum. This allowed us to put forward results analogous to those of Olney and Smith which we should like to discuss briefly here.

The results were obtained from samples annealed at 950°C under a residual pressure of less than 5×10^{-5} mmHg and they may be summarized as follows:

Hypoeutectoid steel <0·7%C The surface loses all traces of oxide, two grain boundary systems appear, one deeply etched corresponding to gamma structure, the other fine cracks corresponding with alpha structure. In association with the gamma structure, geometrical shapes are evident in relief which appear to be twinned crystals (Fig.*A*).

Hypereutectoid steel >0·7% After annealing under vacuum the micrograph often shows striations which are a result of the equilibrium of the metal surface when the crystallographic planes of lower energy are not parallel to this surface[1,2]; in addition as was shown by Olney and Smith a superficial brown layer is formed in relief (Figs.*B* and *C*).

The study of this layer suggested the following conclusions:

(i) Electron diffraction and X-ray examination showed that it was graphite. By second order reflection on the plane (0002) we found c=6·708Å which agrees with the work done by Franklin.[3]

(ii) The formation of this layer is a direct result of the amount of carbon present in the steel, and starts to occur at 0·7% of this element. The layer seems to come from the inside of the metal starting as a dark fringe and continuing as a coalescence in relief (Fig.*B*). Its growth was always greater at the junctions of austenite grains and it is dendritic in appearance (Fig.*D*). The orientation of the crystals of the underlying metal, in relation to the free surface of the sample, affects the phenomenon; some suitably positioned grains are entirely covered when their neighbours remain unchanged (Fig.*E*).

The austenite twins, according to their position, favour or restrict the formation of graphite (Figs.*F* and *G*). X-rays revealed the evidence of a very marked orientation on the plane (0001) of graphite parallel to the surface of the metal. Olney and Smith have given some thought to this structure; we add here the experimental proof.

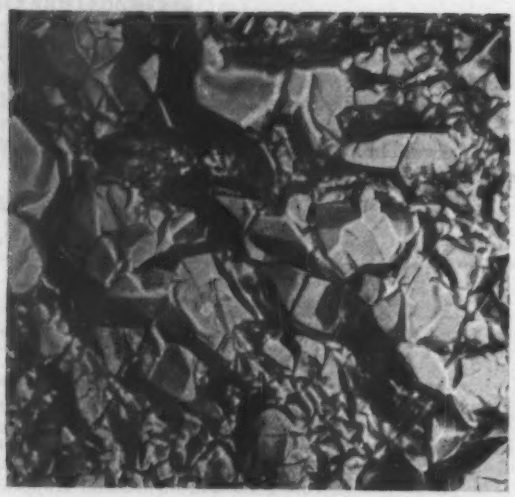
(iii) For a given steel and at a rate of cooling of 20°C/min, a temperature interval may be determined, in which the precipitation of carbon occurs. This allows the postulation of a general rule: it is an area of temperature concentration at the interior which produces the phenomenon (Fig.*H*).

(iv) We have put forward as evidence the fact that superficial graphite formation will not occur unless the residual air pressure is less than 10^{-2} mmHg. Olney and Smith have shown that it is not limited by an atmosphere of very pure argon. We think, therefore, that partial pressure of oxygen is alone involved.

* M. J. Olney and G. C. Smith: *JISI*, 1959, **193**, 107–116.

A *0·4%C steel held for 2 h at 950°C, cooled at 200°C/h, pressure* $<5 \times 10^{-5}$ *mmHg* ×1 800

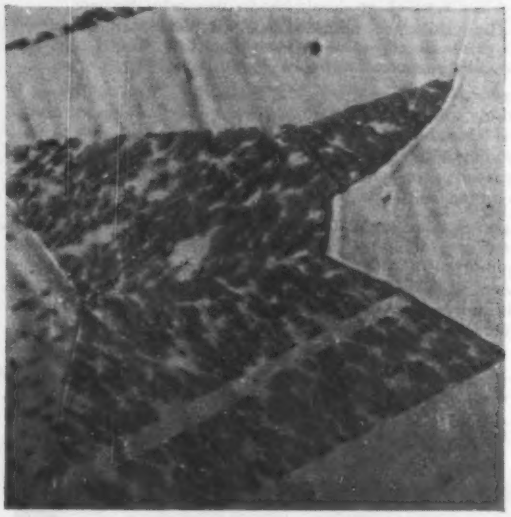
B *0·9%C steel held 2 h at 950°C, cooled at 200°C/h, pressure* $<5 \times 10^{-5}$ *mmHg* ×1 800



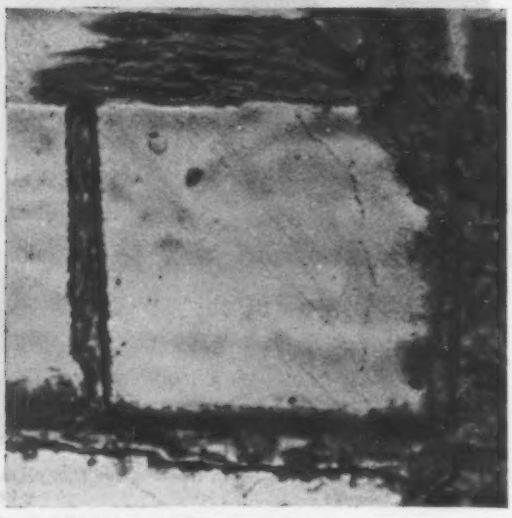
C

D

E



F



G

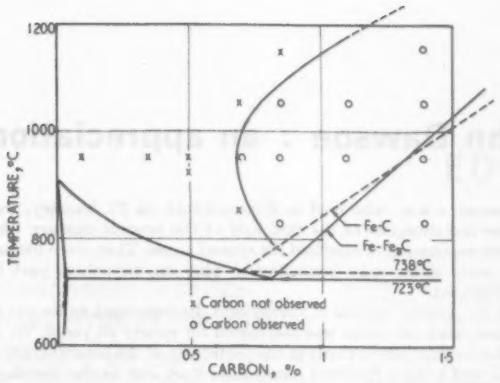
C *1·4%C steel held for 2 h at 950°C, cooled at 200°C/h, pressure $<5\times10^{-5}$ mmHg. Metal surface is entirely covered with graphite; large crystals of graphite are visible* ×550

D *0·9%C steel annealed 2 h at 950°C, cooled at 200°C/h, pressure $<5\times10^{-5}$ mmHg* ×1800

E *0·9%C steel held for 2 h at 950°C, cooled at 200°C/h, pressure $<5\times10^{-5}$ mmHg, showing effect of crystalline orientation* ×1800

F *0·9%C steel held for 2 h at 950°C, cooled at 40°C/min, pressure $<5\times10^{-5}$ mmHg* ×550

G *0·9%C steel* ×1800



H *Region of precipitation of carbon, held 6 h at temperature, cooled 20°C/min, pressure $<10^{-5}$ mmHg, equilibrium diagram after ref.4*

(v) The speed of cooling plays an important part in the deposition of carbon. It is continuous for speeds of 200°C/h, on reaching a speed of 40°C/min, it is present in the form of very clear points (Figs. *F* and *I*).

(vi) It seemed likely that this phenomenon might be explained by a vaporization, under vacuum, of the iron; we have verified that this occurs. We have been able to stop it by placing the sample in a steel container, of very small dead-space, sealed under vacuum by electron bombardment; for the treatment all the container is at the same temperature. Under these conditions of absolutely negligible vaporization of iron we noticed a superficial precipitation of carbon of the same type as the preceding examples.

In conclusion the vaporization of iron, although not negligible in the annealed specimens under vacuum, does not affect the phenomenon and, in agreement with Olney and Smith, we think that it is a question of formation of graphite by decomposition of the cementite according to the stable equilibrium diagram Fe–C. This state is produced with an increase in volume which is important only at the free metal surface. On the other hand, this surface, and more especially the grain boundaries, are the preferred places for precipitation of impurities or crystal defects. It is very probable that these imperfections help the return to a stable iron–graphite state.

The dotted appearance obtained if the rate of cooling is quick enough shows that this graphite formation originates at centres of growth. If we raise the temperatures high enough to make the impurities soluble, the centres of growth are scarce at the metal surface, and we no longer observed carbon there.

AUTHORS' REPLY

Dr **M. J. Olney** (Gillette Industries Ltd) and Dr **G. C. Smith** (University of Cambridge) wrote: We should like to thank Messieurs Bastien and Colombié for their interesting and valuable contribution. We are pleased to learn that our results have been in the main confirmed, and that some further results of a more quantitative nature have been obtained.

The observation made in conclusion (iii) is of considerable interest, as is also the explanation that high austenitizing

I *0·9%C steel held 2 h at 950°C, cooled at 40°C/min* ×1800

temperatures lead to the solution of potential nuclei and the absence of a graphite film on cooling. We obtained no evidence of this ourselves; the formation of graphite was observed on all steels with carbon contents greater than 0·87% (compared with 0·7% of Bastien and Colombié) at all austenitizing temperatures used. We did not, however, explore such a wide range of temperatures and compositions as did Bastien and Colombié; it would be useful to know the compositions of steels used by them, particularly the amounts of Si, Mn, and other elements known to promote or retard graphitization.

We are in complete agreement with all other observations made and we should like to make the following comment on conclusion (iv). Our own view is that surface nucleation of ferrite in hypoeutectoid steels and graphite in hypereutectoid steels probably occurs in all atmospheres. The effects are generally masked, however, by the formation of oxide and the attendant decarburization, and it is only when oxidation and decarburization are prevented by the use of an atmosphere of extremely low oxygen partial pressure that the effects are observed. Extremely pure dry hydrogen behaves in an anomalous way in that it appears to inhibit graphite formation. The surface layers of graphite are replaced by films of cementite, except at high carbon contents (about 1·4%) when a small amount of graphite is observed along with the cementite.

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OBITUARY

Wilfrid John Dawson : an appreciation

Wilfrid John Dawson, C.B.E., who died in Bournemouth on 22 January, was one of the pioneer metallurgists of the first half of the present century who helped to make the reputation of Sheffield for special steels. They were formative years when alloy steels were beginning to play an important part in engineering development.

A student of J. O. Arnold, he was a worthy and distinguished colleague of Sir Robert Hadfield, with whom he was associated for nearly 40 years. W. J. Dawson took an important part not only in the perfection of the manufacturing techniques of the well known Hadfield manganese steel and in the development of many types of cast and wrought products for which the firm of Hadfield became famous, but he was also associated closely with the early production of a range of highly alloyed steels possessed of special heat and corrosion resisting properties, now so widely used and of such importance in the chemical and engineering industries.

A quiet and reserved man, cultured in habit and dignified in bearing, he was an amazingly energetic worker. No man could have been more devoted to his calling, nor more assiduous in effort, whether or not the road of progress was at times rough or the task heavy. He was far-sighted, having a progressive attitude in advance of many of his contemporaries towards the application of research both in the works and by joint action with others. W. J. Dawson was one of those to whom the steel industry must be ever indebted for the growth of the scientific outlook and activity, now so amply evidenced by the development of co-operative research, by the formation of large, well equipped and staffed industrial research laboratories, and by the widening of applied scientific activity in the universities. The list of research committees in both Government and industrial circles with which he was associated, is an earnest of that influence.

To those who knew him more intimately in the works were apparent those many ideas, devices, and suggestions which always helped the job forward and were always so freely and unselfishly given. In his leisure time his greatest source of relaxation was his garden, always beautiful, and in which he always sought to spend his first hour of the day.

As a fitting tribute to his achievement he had the triple awards of the Bessemer Medal, a high honour from his Sovereign, and being appointed an Honorary Vice-President of The Iron and Steel Institute. R.J.S.

Léopold Bouvier

Monsieur Léopold Bouvier, Honorary Director-General of ARBED and an Honorary Vice-President of The Iron and Steel Institute, died in Luxembourg on 12 January.

Born at Clervaux, G.D. Luxembourg, in 1890, Léopold Bouvier graduated as an engineer from the École Centrale de Paris in 1914, and in 1915 he joined the Aciéries Réunies de Burbach-Eich-Dudelange (ARBED) where he remained throughout his career. He was with the Esch rolling-mill division of ARBED until 1929, when he was appointed chief engineer of the central administration. He became successively Director, Joint Director-General, and in 1952 Director-General. In 1955 he was appointed Administrator-Director-General, a post which he resigned in April 1960, when he became honorary Director-General and a member of the directing committee of ARBED.

Monsieur Bouvier's drive and knowledge contributed greatly to the present strength of ARBED. As a young rolling-mill engineer he was interested in new developments and techniques which he applied at ARBED, and later his judgment and experience were invaluable in planning extension and modernization programmes. Léopold Bouvier was a kindly man with a strong sense of social justice which helped to maintain good management-labour relations at ARBED. His death is a great loss to his many friends and associates in Britain and Europe.

EDUCATION

Universities
Technical colleges
Industry

Commonwealth Technical Training Week, 29 May – 4 June

Commonwealth Technical Training Week was first proposed in May 1959 by H.R.H. The Duke of Edinburgh in his capacity as President of the City and Guilds of London Institute, which undertook the administrative organization of the project. The Week aims to make the whole community aware of its responsibility towards young people entering employment and to stress the value of induction and training schemes for varied occupations. Activities will include religious services, civic functions, open days, exhibitions of careers and of work achieved, competitions, films, sport, and social functions.

Counties and local authorities throughout the UK have arranged their own programmes, each with a local flavour in accord with local events and conditions. In Cardiff the formal opening of the Welsh College of Advanced Technology will be included, and in Lincoln the official opening of the large four-storied extension to the Technical College. The British Chambers of Commerce have linked their Apprentice of the Year competition with the Week.

Throughout the Commonwealth similar activities will be taking place. The aim of the Week is not to encourage emigration but the development of existing opportunities. Ten days before the opening of the Week, a ball for commonwealth students will be held at the Royal Festival Hall.

H.R.H. The Duke of Edinburgh will take part in the inaugural function at Guildhall, London, on 29 May. He will attend a service in St Paul's Cathedral on 1 June, and will also make visits during the Week to Scotland, Wales, Northern Ireland, and Birmingham.

Requests for information, enquiries, or other correspondence on the Week should be addressed to: The Secretary, Commonwealth Technical Training Week, 76 Portland Place, London W1.

White paper on technical education

'*Better opportunities in technical education*' (Cmd. 1254, London, HM Stationery Office, 1*s* 3*d*) published recently, contains proposals for a major reconstruction of the system of courses for technicians, craftsmen, and operatives in the technical colleges of England and Wales. At present about 500 000 students attend such courses, and a large increase is likely. The changes have four main objects: to broaden the education given and to provide greater continuity between school and college education; to adapt the system more closely to the needs of industry, in particular the urgent need for technicians; to make more courses available to students, suited to their aptitudes and chosen careers; and to reduce the great wastage at present caused by examination failure and non-completion of courses.

There are ten chief proposals. Students should start at a technical college immediately after leaving school; preliminary courses in evening institutes are to cease. Greater care in selection of students must be developed. The courses will include: National Certificate and Dilploma courses; technician courses devised specifically for particular industries; and courses for operatives. Ordinary National Certificate courses will last two instead of three years, and there will be higher standards of entry. There will be new courses of four or five years specially for technicians. New general courses will be introduced, leading to either technician courses or Ordinary National Certificate and Diploma courses. Craft courses are to be modified and courses for operatives are to be developed. More time should be provided under day release schemes; no student should need to rely only on evening study. Sandwich courses and block release courses will be increasingly developed.

The City and Guilds of London Institute and other examining bodies are now preparing the new general and technician courses. It is hoped to introduce a new course in mechanical engineering in September 1961, to replace the existing scheme in Machine Shop Engineering. A general course combining electrical and mechanical engineering is also in view and should be ready by the same date: 50% of all people covered by the White Paper will take this and it will lead either to an Ordinary National Certificate course, or to the new technician course in mechanical engineering or the existing courses for electrical engineering and telecommunications. Within two years, it is hoped other courses will be in existence, including metallurgy, mining, chemicals, and paints.

The joint committees concerned will announce the changes, necessitated by the White Paper proposals, in the rules relating to the National Certificate and Diploma courses for which they are responsible. Such changes will not operate in respect of the 1961–2 session.

City and Guilds of London Institute

Iron and Steel Operatives' course, 1960 awards

Under 21
Section I, M. J. Rhodes; *Section II*, T. M. Frith.
Open awards
Section I, A. Harpham; *Section IIA* (*Iron-making*), L. Whitaker; *Section IIB* (*Steel-making*), D. F. Cox; *Section IIC* (*Billets, Blooms, Rails, Rods, Sections*), A. Heath; *Section IID* (*Wire and Bright Bars*), E. A. Shaw; *Section IIE* (*Plate, Sheet, Strip*), No award; *Section IIF* (*Forgings, Pressings, Stampings*); B. S. Page; *Section IIG* (*Steel Tubes*), No award; *Section IIH* (*Treatment of special and alloy steels*), A. Buxton.

City and Guilds publications

'Institute Publications 1960–61' gives details of general publications, and question papers that may be obtained on application to the Sales Section, City and Guilds of London Institute, 76 Portland Place, London W1.

BOROUGH POLYTECHNIC

Summer symposia

The Division of Metal Science, Borough Polytechnic, Borough Road, London SE1, announces two symposia:

Welding of rarer metals Thursday, 20 April, morning and afternoon.

Subjects include: electron beam welding, welding of beryllium, welding of uranium, welding of titanium, welding of Zircaloy 2, welding of tantalum, niobium, molybdenum, and tungsten.

Internal stresses in electrolytically produced coatings and their effects on the properties of the basic metals Thursday, 6 July, morning and afternoon.

Subjects include: internal stresses and their measurement, internal stresses in hard chromium and heavy nickel deposits, internal stresses in bright nickel deposits, internal stresses in rhodium and platinum metal deposits, internal stresses in electroforming and electrotyping.

Further details are available from the Divisional Head, Mr G. Isserlis.

Battersea College of Technology

Vacation courses

The fracture of metals
A vacation course, intended to give an overall picture of recent work in this field, is being held on 11–14 April 1961. Lecturers have been selected for their first-hand knowledge of the subject. The topics to be covered will include:

The practical problems of fracture in service
Mechanical testing methods for the assessment of fracture behaviour
Theoretical aspects of fracture
The ductile to brittle transition in ferrous and non-ferrous metals.
The effect of irradiation on fracture behaviour
Temper brittleness in steels
Hydrogen embrittlement of metals
Fracture under creep conditions
Fracture under fatigue conditions.

There will be ample opportunity for questions and discussion.

The inclusive fee is £10 10*s*, and enrolment forms may be obtained from the Secretary (Metallurgy Courses), Battersea College of Technology, London SW11.

Applications of electron diffraction
A vacation course on application of electron diffraction has been arranged by the crystallography section of the Battersea College of Technology for users and potential users of electron diffraction techniques in science and industry. The emphasis will be on practical applications rather than theoretical aspects of the subject. The first day of the course will be devoted to lectures and discussion, while on the second day, visits will be arranged to establishments where electron diffraction apparatus is in use. The inclusive fee for the course is £5 5*s*.

The course is on 13 and 14 April 1961; enrolment forms may be obtained from the Secretary (Crystallography Courses), Battersea College of Technology, London SW11.

Publications

'The Blacksmith'

The Central Youth Employment Executive have issued a second edition of their 'Choice of careers' booklet no.36, *The Blacksmith* (1*s* 6*d*). In a clear, easily followed style the booklet outlines the scope and skills of the trade, from farriery to the making of ornamental ironwork, and gives details of conditions of employment, opportunities, and educational facilities for youngsters who may be interested in this trade.

Programme of the Annual General Meeting 1961

As announced opposite, the Annual General Meeting of The Iron and Steel Institute will be held on **Wednesday and Thursday, 3 and 4 May.** The following sessions will be held at the Institution of Mechanical Engineers, 1 Birdcage Walk, London SW1 (preprints of papers will be sent to those registering for the meeting):

Wednesday 3 May

9.45–10.15 am

Formal business:

Presentation of the Reports of Council and Statement of Accounts for 1960.

Presentations of awards and prizes.

Announcements.

Election of new members.

10.15–11.15 am

Induction of the new President, Sir Charles Goodeve, O.B.E., D.SC., F.R.S.

Presidential Address.

11.15 am–1 pm

Presentation and joint discussion of:

'The pre-refining of blast-furnace iron and the development of the Brymbo oxygen-electric steelmaking process', by E. Davies (Brymbo Steel Works)

'The operations of the oxygen–steam converters at the V.L.N. Steelplant of the Steel Company of Wales', by M. C. Harrison and P. Truscott (Steel Company of Wales Ltd).

Computers in the iron and steel industry

2.30–5 pm

Introductory lecture by W. F. Cartwright and G. W. Thomas (Steel Company of Wales Ltd).

I Computers in research and design

Presentation and discussion of:

'Experience in the UK Steel industry', by D. G. Owen (United Steel Companies Ltd) and R. J. Taylor (BISRA)

'Use of a computer in heat-transfer studies', by M. S. Rhodes (United Steel Companies Ltd)

'Some aspects on predicting blast-furnace behaviour', by A. L. Hodge (Linde Company)

'Design of structures by computer', by L. Morgan and W. M. P. Hutson (United Steel Structural Co. Ltd).

Thursday 4 May

II Computers for process control (in-line)

10–11.15 am

Seminar on the use of computers in cutting up steel product, with contributions from R. H. Baulk (Samuel Fox and Co. Ltd) and W. E. Scott (English Electric Co. Ltd).

11.15 am–12.30 pm

Seminar on the use of computers in mill and furnace control, with contributions from W. E. Scott (English Electric Co. Ltd), G. W. van Stein Callenfels (IJmuiden), and W. J. Slatosky (Jones and Laughlin Steel Corporation).

2.30–5 pm

III Computers in production control and information

Presentation and discussion of:

'The application of a digital computer to the operational problems of the extraction and supply of iron ore', by H. I. A. Archibald (Stewarts and Lloyds Ltd)

'Weekly casting bay programmes', by P. Beynon (Steel, Peech and Tozer)

'A feasibility study in the mechanization of clerical procedures in a large steel company using a computer', by C. Ll. Hopkins and M. E. Court (Steel Company of Wales Ltd)

'Order and production planning', by Bouchaud and Feroldi (SOLLAC).

Joint Symposium on Structural processes in creep

The Iron and Steel Institute and The Institute of Metals are holding a joint Symposium on 'Structural processes in creep' on **Wednesday and Thursday, 3 and 4 May 1961.** The symposium will be held at the Hoare Memorial Hall, Church House, Great Smith Street, London SW1. There will be three technical sessions as follows (chairmen given in parentheses): *Session 1* (Prof. A. G. Quarrell) 3 May, 2.30–5 pm; *Session 2* (Mr W. H. G. Hignett) 4 May, 10 am–12.30 pm; *Session 3* (Prof. J. Nutting) 4 May, 2.30–5 pm.

Participation in the symposium is open to Members of both institutes. There is no registration fee, but those wishing to obtain preprints of the papers may only do so by ordering a bound volume of the proceedings of the symposium, which will be published later this year.

Session 1

'Intercrystalline creep fractures', by A. H. Cottrell (Cambridge University)

'The stress sensitivity of creep', by D. McLean and K. F. Hale (National Physical Laboratory)

'The shear properties of grain boundaries in copper', by S. Harper (British Non-Ferrous Metals Research Association)

'Grain-boundary serrations developed during creep', by A. W. Mullendore and N. J. Grant (Massachusetts Institute of Technology)

'An interpretation of the relationship between creep and fracture', by P. W. Davies and B. Wilshire (University College, Swansea).

Session 2

'A study of the alloying behaviour of an austenitic base containing 20%Ni, 20%Cr, and 20%Co', by H. C. Child (Jessop-Saville Ltd)

'Metallographic features of creep-resistant alloys', by J. Nutting (Leeds University) and J. M. Arrowsmith (Cambridge University)

'Some correlations between structure and stress–rupture properties of nickel–chromium alloys strengthened with titanium and aluminium', by E. A. Fell, W. I. Mitchell, and D. W. Wakeman (Mond Nickel Co. Ltd)

'The effect of structure on the creep properties of titanium alloys', by A. L. Dalton (Jessop-Saville Ltd), D. Webster (Aeon Laboratories), and H. C. Child (Jessop-Saville Ltd).

Session 3

'An investigation of the creep ductility of 18–12–1Nb and related steels', by H. W. Kirkby and R. J. Truman (Brown-Firth Research Laboratories)

'Some causes of variation in high-temperature strength of steels with particular reference to the silicon content', by J. Glen, J. Lessels, R. R. Barr, and G. G. Lightbody (Colvilles Ltd)

'Structural aspects of creep-resisting steel', by K. J. Irvine, J. D. Murray, and F. B. Pickering (United Steel Companies Ltd)

'Some factors affecting the creep–rupture performance of a 3%Cr–Mo–W–V steel at 550°C', by J. D. Hodkin, L. G. Finch, and E. W. Colbeck (Hadfields Ltd)

'The variability of the creep resistance of mild steel', by N. P. Allen and L. M. T. Hopkin (National Physical Laboratory)

'The structure and properties of 1%Cr–0·5%Mo steel after service in CEGB power stations', by L. H. Toft and Ruth A. Marsden (Central Electricity Research Laboratories).

NEWS | *Announcements and News of Science and Industry*

THE IRON AND STEEL INSTITUTE

Cooperation with The Institute of Metals and The Institution of Metallurgists

The Councils of The Iron and Steel Institute, The Institute of Metals, and The Institution of Metallurgists have set up a Joint Consultative Committee with the object of ensuring closer cooperation between the three Societies.

They have also adopted, with effect from 1 January 1962, revised arrangements for joint membership of the Institution and of one or both of the Institutes.

Details will be announced at the Annual General Meeting on 3 May, 1961.

Annual General Meeting 1961

The Annual General Meeting of the Institute will be held in London on **Wednesday and Thursday, 3 and 4 May 1961.** There will be two parallel technical sessions, devoted to 'Computers in the iron and steel industry' and to 'Structural processes in creep' respectively. The latter will be a joint meeting with The Institute of Metals. Full details are given opposite.

The Dinner for Members will be held at Grosvenor House, Park Lane, London W1, on the evening of **Wednesday, 3 May.**

Special meeting in USA October–November 1961

A notice has been sent to all Members giving the outline programme for the Institute's Special Meeting in the USA and Canada this year. As previously announced, the Council has accepted with pleasure an invitation from the Metallurgical Society of the American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME) to visit the USA in October and November.

The provisional programme provides for an official welcome in New York City on **Thursday, 19 October,** but it is anticipated that some members will arrive a day or two earlier.

Members will be able to travel to and from the USA by normal sea and air routes, but in addition aircraft will probably be chartered for Atlantic crossings at substantially reduced cost. Provisional dates for these crossings are: to New York, **Tuesday 17 October;** from New York, **Wednesday, 8 November 1961.**

Preliminary estimates of cost are included in the programme recently circulated to members.

Autumn General Meeting 1961

The Institute's Autumn General Meeting will be held in London on **Wednesday and Thursday, 29 and 30 November 1961.** The technical sessions will be devoted to a symposium on 'The future of ironmaking', and to a number of papers on scientific subjects. Full details will be published later in the *Journal*.

NEWS OF MEMBERS

Mr **D. T. Barritt** has been appointed deputy chairman of Simon Engineering Ltd; he has also been appointed director and chairman of Henry Simon (Holdings) Ltd. He has relinquished the post of joint managing director of Simon Carves Ltd, but remains on the board.

Mr **G. H. Black** has been appointed managing director of Kestner Evaporator and Engineering Co. Ltd.

Mr **C. S. Burch** has retired as chairman and from the board of Halesowen Steel Company owing to ill-health.

Mr **D. L. Campbell,** M.C., has resigned from the board of Campbell, Gifford and Morton Ltd on his appointment as Managing Director of Davy-Ashmore Export Company Limited, the newly formed subsidiary of Davy-Ashmore Limited.

Mr **T. R. Craig,** O.B.E., (*Member of Council*), has been appointed chairman of BISC (Ore) Ltd.

Mr **T. Davison** has retired from the post of mill manager and roll designer of the Lanarkshire Steel Co. Ltd, after 35 years' service with the Colvilles organization.

Mr **A. M. Dickson** has joined James Booth Aluminium Ltd as a project engineer.

Mr **M. F. Dowding** has been appointed a director of Davy–Ashmore Ltd.

Mr **M. A. Fiennes** (*Member of Council*) is now chairman of Ashmore, Benson, Pease and Co. Ltd and of P. G. Engineering Ltd.

Mr **C. Frenkel** has been appointed consultant to Wean-Miles Ltd. He remains a consultant to John Miles and Partners (London) Ltd.

Mr **L. J. A. Haywood** has resigned from the post of chief chemist at Catton and Co. Ltd, Leeds, and is now works manager at the Silbond Refractory Manufacturing Company, Sheffield.

Mr **A. H. Ingen-Housz** (*Past President*) has been made an officer of the Belgian Order of the Crown.

Mr **T. Jolly** (*Member of Council*) has resigned from the board of Guest Keen and Nettlefolds (South Wales) Ltd.

Sir **Walter Benton Jones** has retired from the board of Davy–Ashmore Ltd.

Mr **P. R. Marchant** has left Johnson, Matthey and Co. Ltd, to join the Copper Development Association.

Dr **B. J. Pearcey** has been appointed lecturer in metallurgy at the Sheffield College of Technology.

Mr **L. R. P. Pugh** has been appointed to the board of Guest Keen and Nettlefolds (South Wales) Ltd.

Mr **J. W. Roberts** has joined Clugston Cawood Ltd, as foam plant manager of their North Lincoln slagworks, Scunthorpe.

Mr **T. B. Reddy** has joined the board of BISC (Ore) Ltd.

Mr **T. M. Shore** has left BISRA to join the Morgan Construction Company.

Mr **B. Chetwynd Talbot** (*Vice-President*) has joined the board of BISC (Ore) Ltd.

Dr **W. S. Walker** (*Hon. Member of Council*) has joined Campbell, Gifford and Morton Ltd.

Mr **H. W. A. Waring,** C.M.G. (*Member of Council*), has been appointed to the board of Guest Keen and Nettlefolds (South Wales) Ltd.

Mr **C. R. Wheeler,** C.B.E. (*Past-President*), has resigned from the board of Guest Keen and Nettlefolds (South Wales) Ltd. Mr Wheeler has also resigned chairmanship of BISC (Ore) Ltd, but remains on the board.

Mr **C. E. Wrangham** has resigned from the boards of Ashmore, Benson, Pease and Co. Ltd and P. G. Engineering Ltd.

Obituary

Professor **Alfred Campion** (*Andrew Carnegie Gold Medallist* 1903) of Glasgow, on 9 January 1961.

Cecil Cyprian Higgens (*elected* 1952) of Worthing, Sussex, on 10 January 1961.

Señor **L. Ibarreta Peisnce** (*elected* 1926), *of* Bilbao, Spain, in 1960.

John Roland Spanswick (*elected* 1959) of Chipstead, Surrey, on 4 December 1960.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

Desulphurizing of steel: BISRA experiments

During the refining period in an electric-arc furnace the hydrogen content of steel can rise to undesirable levels. Extremely long refining times are necessary for very low sulphur steels; if the process can be speeded up, the danger of hydrogen contamination can be cut down. BISRA's steelmaking division has made a number of experiments in which the direct injection of powdered desulphurizing reagents into the metal bath of an electric-arc furnace has been established as an effective means of quickly desulphurizing steel. For quick desulphurization to very low levels the metal must be strongly deoxidized, either by previous treatment, e.g. with aluminium, or by including magnesium or aluminium in the injectant as alloy or element.

Full details of these experiments, including tables and accounts of the cost on an industrial scale can be found in BISRA report SM/AC/46/60, and a short description in BISRA Summary 159 'The rapid desulphurizing of steel', both of which may be had from the Information Officer, BISRA, 11 Park Lane, London W1.

'Open Days' at Sheffield Laboratories

The British Iron and Steel Research Association will hold two 'Open Days' at its Hoyle Street, Sheffield Laboratories on Thursday and Friday, 15 and 16 June. These premises house three of BISRA's divisions: steelmaking, metallurgy (general), and mechanical working. The steel user section, which operates an important advisory service to industry generally, is also there.

Among displays and demonstrations planned by steelmaking division will be the latest developments in continuous casting, and work on spray refining and rapid desulphurization. The mechanical working division's projects on show will include a recently developed rapid annealing system. The metallurgy division's projects will reflect its general preoccupation with the purification of steel, e.g. jet degassing, vacuum casting, work on improved speed and accuracy in analysis, and the production of high-temperature steels.

THE INSTITUTE OF METALS

Elections to Council

The following members have been declared elected to fill vacancies that occurred on the Council of The Institute of Metals at the Annual General Meeting on 21 March:

President: Professor H. O'Neill (Head of the Department of Metallurgy, University College of Swansea, University of Wales)

Past-President: Sir Ronald Prain, O.B.E. (Chairman and President, Rhodesian Selection Trust Ltd)

Vice-Presidents: Mr W. F. Randall (Deputy Chairman and Managing Director, Telcon Metals, Ltd) and The Right Hon. The Earl of Verulam (Chairman, Enfield Rolling Mills Ltd)

Ordinary Members of Council: Mr N. I. Bond-Williams (Managing Director, The Aston Chain and Hook Co., Ltd), Professor A. H. Cottrell, F.R.S. (Goldsmiths' Professor of Metallurgy, University of Cambridge); and Mr G. A. Rider (Deputy Managing Director, Birmid Industries Ltd).

The Council has elected The Earl of Verulam to serve as Senior Vice-President for the year 1961–62.

AFFILIATED LOCAL SOCIETIES

Joint Meeting with Sheffield societies, 12 April 1961

A joint meeting of The Iron and Steel Institute, The Sheffield Metallurgical Association, and The Sheffield Society of Engineers and Metallurgists is being held at the Engineering Lecture Theatre, The University, St George's Square, Sheffield 1, from 2.15 to 6 pm on Wednesday, 12 April 1961. Four research papers from the British Iron and Steel Research Association (all published in the *Journal* of The Iron and Steel Institute), are to be presented and discussed.

The papers for discussion are as follows (dates in parentheses refer to the month of publication in the *Journal*):

'The effect of heat-treatment and microstructure on the high-temperature ductility of 18%Cr–12%Ni–1%Nb steels', by *K. J. Irvine, J. D. Murray,* and *F. B. Pickering,* United Steel Companies Ltd (October 1960)

'Some ductility aspects of 18–12–1Nb steel', by *R. J. Truman* and *H. W. Kirkby,* Brown Firth Research Laboratories (October 1960)

'Heat-affected zone cracking in welded high-temperature austenitic steels', by *R. N. Younger* and *R. G. Baker,* British Welding Research Association (October 1960)

'Microstructural causes of heat-affected zone cracking in heavy section 18–12–Nb austenitic stainless steel welded joints', by *N. E. Moore* and *J. A. Griffiths,* Associated Electrical Industries (Manchester) Ltd (January 1961).

The meeting is open to all members of the three societies and their guests. Those wishing to attend should apply for the necessary form to The Secretary, The Iron and Steel Institute, 4 Grosvenor Gardens, London SW1, to whom it must be returned by not later than 5 April 1961. Admission to the meeting will be by ticket only.

SHEFFIELD METALLURGICAL ASSOCIATION

Officers and Members of Council

The Council of the Association this year consists of the following officers and members:

President Mr J. E. Russell
Vice-Presidents Dr A. H. Sully, Mr B. E. G. R. Wilkinson, Mr H. W. Kirkby, and Mr J. F. Hinsley
Hon. Secretary Dr D. Hardwick
Hon. Treasurer Mr J. Burnett
Hon. Librarian Mr T. G. Chadwick
Hon. Proc. Secretary Mr J. F. Hinsley
Members of Council Messrs W. H. Bailey, E. Ineson, K. C. Barraclough, G. Parkin, J. H. Spalton, M. J. Heeley, J. H. Woodhead, Dr K. W. Andrews, P. Mitchell, and G. W. Giles.

THE INSTITUTION OF MECHANICAL ENGINEERS

Change of Secretary

The Council announce that the Secretary, Mr Brian G. Robbins, M.SC.(ENG.), F.C.G.I., M.I.MECH.E., recently expressed a wish to retire before reaching the normal retiring age, and they have accepted his resignation with regret. The Council have appointed Mr Kenneth H. Platt, M.B.E., B.SC., M.I.MECH.E., to succeed Mr Robbins on 1 June 1961. Mr Robbins was appointed Secretary on 19 January 1951.

Mr Platt joined the Institution staff in November 1952, was appointed Assistant Secretary in May 1953, and Deputy Secretary in January 1956. He became an Associate Member of the Institution in 1937 and transferred to Member in 1953.

THE INSTITUTION OF CHEMICAL ENGINEERS

European Federation of Chemical Engineering: Third Congress

The third congress is being organized by The Institution of Chemical Engineers and will take place at Olympia, London from 20 to 26 June 1962.

It will incorporate three technical meetings: a three-day symposium on 'Interaction between fluids and particles'; a one-day meeting on 'Process optimization'; and a one-day symposium on 'The handling of solids'.

The handling of solids Under this broad heading it is proposed to consider the behaviour of solids as process materials in bulk form. The meeting will be concerned with interaction between solid particles and other particles, and between solid particles and apparatus. The scope of the programme includes: agglomeration; conveying, size separation; storage of solids; weighing; feeding at controlled rates; and methods of examining solids to describe their bulk properties.

Process optimization has been chosen as a subject because of the important contribution it can make to reduction of economic costs. The main techniques reviewed will include those based on chemical and physical principles, on mathematics, and arising from developments in automatic control theory, computer development, and work study.

Suggestions for papers for inclusion in the programme are invited, and should be sent with title, subject, summary or other brief description to: The General Secretary, The Institution of Chemical Engineers, 16 Belgrave Square, London SW1, as soon as possible and by not later than 30 April 1961. Further information may be had from the Institution at the address given.

BRITISH CONFERENCE ON AUTOMATION AND COMPUTATION

Automation—men and money

As announced last December by Sir Walter Puckey, Chairman of The British Conference on Automation and Computation, arrangements are well in hand for a conference 'Automation—men and money', to be held in Harrogate on 27–30 June.

BCAC was formerly a federation of three separate groups concerned respectively with the engineering application of automation, automatic control and computation, and the sociological and economic aspects, which merged at the end of last year to form a single Council of which The Iron and Steel Institute is a member.

The conference at Harrogate will consist of six sessions, four of which will be devoted to the presentation and discussion of papers on economic and social aspects of automation, both internal to the firm and in a wider context; and one to case histories illustrating the preceding discussions. Sir Walter Puckey will be chairman at the final plenary session.

Further details are available from the conference organizers, c/o The British Institute of Management, 80 Fetter Lane, London EC4.

INSTITUTE OF WELDING

Spring meeting

The 1961 Spring Meeting of the Institute of Welding will be held in London between 25 and 28 April, so as to coincide with the Engineering, Marine, Welding, and Nuclear Energy Exhibition at Olympia.

The theme of the meeting will be 'Recent developments in the welding and allied processes'. During the meeting the Fourth Annual Lecture entitled 'Welding in the non-ferrous field' will be given by Dr N. P. Inglis. Admission to the lecture will be by ticket only. Further details are available from the Secretary, 54 Princes Gate, London SW7.

E. Davies

R. B. Waterhouse

CONTRIBUTORS TO THE JOURNAL

E. Davies—Managing director, Brymbo Steel Works.
Emrys Davies joined the Brymbo Steel Co. in 1920. In 1937 he was appointed assistant to the Technical Director and was responsible for the development and research at the Brymbo Works. In 1940 he was appointed melting-shop manager and in 1943 took control of both blast-furnace and steelplant. He was appointed works manager in 1946, works director in 1956, and managing director in 1961. He is a director of John Lysaght's Scunthorpe Works; Guest Keen Iron and Steel Works, and the GKN Steel Company Ltd. Mr Davies was responsible for the development of the oxygen/electric steelmaking process at Brymbo.

R. B. Waterhouse, M.A., PH.D.—Department of Metallurgy, Nottingham University.
Dr Waterhouse was born in 1922 and educated at Colfe's Grammar School, Lewisham, and Pembroke College, Cambridge. He has researched at the Fulmer Research Institute, and at Cambridge in the Colloid Science Department. In 1956 he became Lecturer in Metallurgy at Nottingham University, where he is also Warden of Wortley Hall. He is a Fellow of The Institution of Metallurgists.

J. C. Levy, M.S., B.SC.(ENG.)—Reader in mechanical engineering, Northampton College of Advanced Technology, London.
John Court Levy was born in London in 1926 and educated at Owens School, Islington, and the Imperial College of Science and Technology where he gained his B.SC. honours degree in mechanical engineering in 1946. After five years in industry he joined the Northampton College of Advanced Technology (then the Northampton Polytechnic) as assistant lecturer. In 1953–54 Mr Levy was on a Fulbright Award to the University of Illinois, USA, where he gained his M.S. degree in theoretical and applied mechanics. He returned to Northampton College where he is now reader in mechanical engineering, concerned with teaching and research in the strength and properties of materials.

S. L. Kanitkar, M.SC.(ENG.).
Sadashiv Laxman Kanitkar was born in India in 1929. He gained a B.SC. in physics from the University of Poona in 1952, then came to London and studied at Northampton College where he gained his B.SC. in engineering. He was then employed at the College as a graduate research assistant and obtained his M.SC. in engineering. He has now returned to India where he is engaged on the design of agricultural machinery.

H. I. A. Archibald, B.SC.ECON.—Senior Programmer, Computing and Calculating Department, Stewarts and Lloyds Ltd, Corby.
Mr Archibald was born in 1931 and educated at the Alloa Academy and the Dundee School of Economics. He graduated B.SC.ECON.

(HONS.) London University in 1956, and in the same year he joined the Programming Division of LEO Computers Ltd. He then joined the computer staff of Stewarts and Lloyds, Corby, as a programmer. Mr Archibald has been senior programmer since September 1959, concerned mainly with commercial data processing applications.

H. I. A. Archibald

NEWS OF SCIENCE AND INDUSTRY

Death of Sir A. Croft

The death occurred on 13 February of Sir Arthur Croft, chairman of Crofts Engineers (Holdings) Ltd, at his home near Leeds. He was 74.

New industrial film

The Steetley Story, a colour film showing the wide variety of the company's products and their application, was recently released by The Steetley Company Ltd, Worksop, Notts. The film shows how raw materials are acquired and processed into an astonishing variety of products; at a plant in Hartlepool, refractory magnesia is produced from dolomite and seawater, while in Canada dolomite is quarried by one of the company's subsidiaries for building purposes.

These diverse activities are coherently presented in a film which avoids being dull or over-technical. It is available on loan from the company, in 16 and 35 mm.

Honour for J. F. Thompson

Dr John F. Thompson, honorary chairman of the International Nickel Company, has been elected to honorary membership of the American Institute of Mining, Metallurgical, and Petroleum Engineers, in recognition of his outstanding contributions to many branches of metallurgy.

ISCON appointment

Sir Peter Roberts, BT., M.P., Chairman of The Wellman Smith Owen Engineering Corporation Ltd, has been appointed Deputy Chairman of the Indian Steelworks Construction Company Limited.

ISCON, a consortium of 13 of the leading British engineering Companies, is building the £120 m. Durgapur Steelworks, now nearing completion near Calcutta, for the Government of India.

Parkfield Foundries (Tees-side) Limited

A company was formed recently as a private limited liability company and registered under the name 'Parkfield Foundries (Tees-side) Limited'.

The Company took over the Ashmore, Benson, Pease Foundry as a going concern, Ashmore Foundry contracts were assigned to the new Company.

The first directors of Parkfield Foundries (Tees-side) Limited are: Mr G. T. Cantlay, Chairman, the Hon. Anthony Berry, Mr E. K. Gould, and Mr G. Hobman. Mr G. B. Taylor, who was Sales Manager of Ashmore's Works Division, and formerly Foundry Manager of the A.B.P. Foundry for a period of 15 years, was appointed Managing Director of the new Company.

The Company offered employment to most of the staff and workpeople engaged in the Foundry. It began trading on 13 February.

New Davy–Ashmore subsidiary

Davy–Ashmore Limited announce the formation of a new subsidiary *Davy-Ashmore Export Company Limited*, to manage and develop the overseas selling and engineering organization. The Directors are: Mr M. A. Fiennes (Chairman), Mr D. L. Campbell, M.C. (Managing Director), Mr D. M. R. Brown, Mr M. F. Dowding, Mr T. K. Hargreaves, D.S.O., Mr C. Robson, Mr R. W. Rutherford, Mr H. M. Sutherland, Mr H. H. Utley. Mr L. Davis is Secretary. The offices of the new company are at 15 Portland Place, London W1 (LAN 5588).

Contract news

The General Electric Company have received two contracts to supply ore-handling plant: to Appleby-Frodingham's Scunthorpe works, plant worth £1 m., and to Colville's Ravenscraig works, equipment valued at about £500 000.

Lodge-Cottrell have contracted to supply the Anglo-American Corporation of South Africa with gas cleaning plant: the contract is worth roughly £85 000. They have also (through their licencees, *Auxeltra Electrification et Travaux Speciaux SA*, Brussels) a contract to supply two precipitated units for Halinogorsk, USSR, worth about £70 570; and one for similar equipment for the Mol Power Station, Belgium, worth about £90 000. They also have orders for a gas cleaning plant for Guest Keen Iron and Steel Company; and a scarfer fume cleaning plant for Richard Thomas and Baldwins.

Wild–Barfield Electric Furnaces Ltd have received an order for a continuous shaker hearth furnace installation from L. H. Newton Ltd, Birmingham.

Powell Duffryn-Coppee have been given an order for 25 coke-ovens for the Rhodesian Iron and Steel Company's steelworks at Redcliff, Southern Rhodesia.

Fantak Ltd have received an order from Head Wrightson (Teesdale) Ltd for an 18 MeV Siemens Betatron.

W. C. Heraeus GmbH, Hanau, have been given a contract to supply a vacuum arc melting furnace to Firth-Brown, Sheffield.

FORTHCOMING CONFERENCES AND EXHIBITIONS

1st International Congress on Metallic Corrosion

The first International Congress on Metallic Corrosion takes place at the Imperial College of Science and Technology, Exhibition Road, South Kensington, London SW1 from 10 to 15 April.

Affiliation to the Congress is necessary in order to take part in the technical discussions, and all members of the Corrosion Group of the Society of Chemical Industry and The Iron and Steel Institute have been circulated with a brochure giving titles of papers and of plenary lectures. Papers have been preprinted and will not be read in detail at the Congress, the accent being on comment and discussion.

Other details appear on the Group's current programme card which is available from the Secretary, 14 Belgrave Square, London SW1.

Engineering, Marine, Welding, and Nuclear Energy

This year's Engineering, Marine, Welding, and Nuclear Energy Exhibition is being held at Olympia, London, from 20 April to 4 May. It will be open daily except Sundays, from 10 am to 6 pm, and from 10 am to 8 pm on 1–3 May. Tickets are available to Members of The Iron and Steel Institute on application to the Secretary.

Symposium on metallurgical applications of electronic bombardment

The Société Française des Ingénieurs et Techniciens du Vide are to hold a symposium on 21 April 1961 in Paris, on 'Applications métallurgiques du bombardement électronique'. Further details may be had from Madame J. Mainier, Secrétariat Administratif, 147 ter A, Boulevard de Strasbourg, Nogent S/Marne–Seine, France.

VDI meetings

The Verein deutscher Ingenieure has announced the following meetings:

26–28 April, Aachen: The present position of dust removal techniques

22–23 June, Mannheim: Works noise (arranged by the Working Group on Reduction of Noise)

25–26 Oct., Stuttgart: Automation of production.

Malleable Iron conference

A conference on this subject is to be held on Thursday 27 and Friday 28 April 1961 at The University of Birmingham.

The object of the conference is to promote discussion of some of the current problems and ideas in malleable iron research, properties, and applications. Speakers introducing different subjects will review present knowledge in the field and indicate some of the current problems leading to a general discussion of the three main topics: malleable iron metallurgy; properties of the malleable iron; and its production.

The registration fee for the course is 10*s* 6*d*; enquiries should be addressed to The Chief Technician, Department of Industrial Metallurgy, The University, Edgbaston, Birmingham 15.

Industrial Finishes Convention

A programme of technical papers will be delivered before delegates at the First International Industrial Finishes Convention in London. The Convention, which is being planned to run simultaneously with the First International Industrial Finishes Exhibition at Earls Court, London, between 8 and 11 May 1961, will serve as a centre of discussion covering finishing progress in all branches of industry.

The registration of delegates to the Convention has now begun. All delegates will receive a free catalogue and admission to the exhibition as well as the right to be present at all Convention sittings and to take part in the discussions on individual papers. The registration fee is £1 1*s*, or £3 3*s* for those wishing to have printed copies of the papers.

The Convention is being organized by Scientific Surveys Ltd, 97 Old Brompton Road, London SW7 (KNI 9360), who are also organizing the exhibition.

Mesucora 61

An international exhibition covering measurement, control, regulation, and automation, MESUCORA 61 will be held from 9 to 17 May 1961 in the exhibition hall of the Centre National des Industries et Techniques (CNIT), Paris. It is organized by the Mesucora association whose members are French trade organizations interested in these fields. The annual exhibition of the French Physical Society will be held within the compass of MESUCORA 61. Simultaneously an international congress on 'Recent progress in the fields of measurement control, regulation, and automation', and the precision engineering biennial meetings will take place.

Further information may be obtained from: the Congress Secretariat, CNIT, 20 rue Carpeaux, Puteaux (Seine), France.

Second international conference of the Institute of Materials Handling

The second international conference of the Institute of Materials Handling will be held at the Prince of Wales Hotel, Southport, from 10 to 12 May 1961. The conference will cover construction, procurement, manufacture, and transport and distribution, through selected industries. Delegates will be able to select visits from among some 22 works, and there is to be a suitable programme for ladies. The fee for the conference including texts of the papers is £2 2*s*. Further details may be had from the Institute of Materials Handling, 32 Watling Street, London EC4.

CHANGES OF ADDRESS

As of 1 January 1961, Carbonifera Unida de Palau, S.A., and Carbonifera de Barroterán, S.A., merged with Mexicana de Coque y Derivados, S.A. de C.V., only the last company remaining.

DIARY

6 Apr. INSTITUTE OF METALS, LONDON LOCAL SECTION—Annual General Meeting and lecture, '*Physical methods of analysis for major alloying constituents*', by K. M. Bills—17 Belgrave Square, London SW1, 6 pm.

10–15 Apr. INTERNATIONAL CONGRESS ON METALLIC CORROSION—Imperial College, S. Kensington, London SW7.

10 Apr.–13 May SEVENTH COMMONWEALTH MINING AND METALLURGICAL CONGRESS—South Africa, 10 April–6 May; Northern Rhodesia, 7–13 May.

11–14 Apr. 2ND INTERNATIONAL REFRIGERATION AND AIR CONDITIONING EXHIBITION—Earls Court, London—10 am to 6 pm.

12 Apr. THE IRON AND STEEL INSTITUTE AND AFFILIATED SHEFFIELD SOCIETIES—Joint meeting—University, Sheffield, 2.15 pm. (*See* p.326, this issue.)

12 Apr. LEEDS METALLURGICAL SOCIETY—Lecture, '*Some aspects of the metallurgy of fasteners*', by R. J. Allsop—University Staff House, University Road, Leeds, 6.30 pm.

12–14 Apr. INTERNATIONAL SYMPOSIUM ON AGGLOMERATION—Philadelphia.

13 Apr. EAST MIDLANDS METALLURGICAL SOCIETY—Annual General Meeting and lecture, '*Recent work on cold forming and extrusion*', by N. S. Angus—Derby and District College of Art, Derby, 7.30 pm.

14 Apr. WEST OF SCOTLAND IRON AND STEEL INSTITUTE—Annual General Meeting and lecture, '*Heating and oxidation in the basic OH process*', by I. M. Mackenzie, D. Hadfield, T. Urie, and Mrs A. Donald—39 Elmbank Crescent, Glasgow, 6.45 pm.

17–18 Apr. POWDER METALLURGY JOINT GROUP—Discussion, '*Appraisal of powders for pressing and sintering*'—Royal Commonwealth Society, Craven Street, London W1, 2.30 pm. (See p.295, this issue.)

17–18 Apr. INSTITUTE OF PHYSICS AND THE PHYSICAL SOCIETY—Conference, '*Nuclear energy*'—University of Birmingham.

17–20 Apr. ERGONOMICS RESEARCH SOCIETY—Annual Conference—Bristol.

20 Apr. LIVERPOOL METALLURGICAL SOCIETY—Lecture, '*Continuous casting of aluminium alloys*', by Dr W. M. Doyle and Annual General Meeting—Department of Metallurgy, The University of Liverpool, 7 pm.

20 Apr.–4 May ENGINEERING, MARINE, WELDING, AND NUCLEAR ENERGY EXHIBITION—Olympia, London W14.

21 Apr. WEST OF ENGLAND METALLURGICAL SOCIETY—Lecture, '*Temperature measurement*', by J. A. Hall—College of Technology, Ashley Down, Bristol 7, 7.30 pm.

24 Apr. INSTITUTION OF CHEMICAL ENGINEERS—Lecture, '*Fluid-fuel nuclear reactors*', by A. M. Weinberg—Geological Society, Burlington House, London W1, 5.30 pm.

25–27 Apr. INSTITUTE OF WELDING SPRING MEETING—Technical Sessions—54 Princes Gate, London SW7, 9.30 am.

25 Apr. SOCIETY OF INSTRUMENT TECHNOLOGY—Lecture, '*Instrumentation in the iron and steel industry*', by A. H. Pople—Manson House, 26 Portland Place, London W1, 7 pm.

26 Apr. SOUTHAMPTON METALLURGICAL SOCIETY—Annual General Meeting and lecture, '*The development of cast metals*', by Dr H. T. Angus—Technical College, St Mary's Street, Southampton, 7.15 pm.

27–28 Apr. MALLEABLE IRON CONFERENCE—University of Birmingham, Edgbaston 15.

28 Apr. DSIR—Open Day—Warren Spring Laboratory, Stevenage.

3–4 May THE IRON AND STEEL INSTITUTE—Annual general meeting and dinner (*see* p.325, this issue).

8 May SOCIETY OF CHEMICAL INDUSTRY—Annual general meeting—14 Belgrave Square, London SW1, 6 pm.

8–11 May DSIR—Open day—National Physical Laboratory, Teddington.

8–11 May INDUSTRIAL FINISHES CONVENTION—Earls Court, London.

8–12 May AMERICAN FOUNDRYMEN'S SOCIETY—1961 castings congress—San Francisco.

BRITISH IRON AND STEEL INDUSTRY TRANSLATION SERVICE

The following translations are now available, in addition to those given on page 250 of the March 1961 issue of the *Journal*.

When ordering, please make a note of the number in bold type.

The determination of the frictional losses on roll neck journals when water is used as a coolant and lubricant. (From German.) WENGER, E., *Stahl Eisen*, 1959, *79*, 3 Sept., pp.1263–1268. (£4) **[1529**

The 'Bunker on wheels'. A study of ore transport by rail from the ship to the blast-furnace. (From German.) DILLI, G., *Stahl Eisen*, 1959, *79*, 23 July, pp.1041–1057. (£10) **[1587**

The application of the describing function method for determining the stability of sampled data control systems. (From German.) OPPELT, W., *Regelungstechnik*, 1960, *8*, Jan., pp.15–18. (£2 15*s*. 0*d*.) **[1697**

Continuous thickness measurement during rolling by means of radiation. (From German.) HART, H., *Z. Metallk.*, 1960, *51*, Feb., pp.120–131. (£6 15*s*. 0*d*.) **[1731**

The burning of coke. (From German.) SCHENCK, H. *et al.*, *Stahl Eisen*, 1959, *79*, Dec., pp.1933–1938. (£4) **[1751**

Interaction between tool and workpiece materials during the cutting of metals. (From German.) LOLADSE, T. N., *Ind.-Anzeiger* (Essen), 1959, *81*, 4 Aug., pp.21–26 (991–996). (£5 5*s*. 0*d*.) **[1762**

Hydraulic bloom and slab shears. (From German.) HERTL, A., *Tech. Mitt.*, 1958, *51*, Oct., pp.513–519. (£5 15*s*. 0*d*.) **[1764**

The equilibrium of forces in rolling with lateral spread. (From Russian.) PAVLOV, I. M., *Stal'*, 1947, (1), pp.39–48. (£5 15*s*. 0*d*.) **[1826**

Radioactive marking technique for investigating metallurgical processes in steelworks. (From German.) PRÖBSTL, G. H., *Stahl Eisen*, 1960, *80*, 23 June, pp.863–877. (£9 5*s*. 0*d*.) **[1827**

Mechanical data-recording as an aid to quality control. (From Italian.) CASADIO, M., Conference on statistical quality control (Convegno sul controllo statistico della qualità), AICQ, Milan, 22–23 Oct., 1959. (£1 15*s*. 0*d*.) **[1864**

Applications of rectifiers to rolling mills. (From French.) MATTA, M., *Bulletin AIM*, 1959, April–May, pp.323–342. (£5 10*s*. 0*d*.) **[1869**

Non-destructive examination of extreme line casing. (From German.) HAUK, V., and ROETHER, K., *Erdöl Zeitschrift*, 1959, (11), Nov., pp.436–438. (£2 5*s*. 0*d*.) **[1878**

Choice of a steel with high yield point for welded containers for service at high temperatures and pressures. (From French.) ROUX, J. H., *Rev. Mét.*, 1960, *57*, June, pp.507–519. (£5 15*s*. 0*d*.) **[1889**

Continuous casting in Austria. (From German.) TARMANN, B., *Radex Rund.*, 1959, *6*, Dec., pp.704–713. (£4 15*s*. 0*d*.) **[1896**

The cranes of the iron and steel works at Rourkela in India. (From German.) RIELÄNDER, H., *Stahl Eisen*, 1960, *80*, 26 May, pp.756–763. (£4 15*s*. 0*d*.) **[1913**

Construction of the North-West oil pipe line from Wilhelmshaven to Cologne–Wesseling. (From German.) SCHWARZBACH, K., *Der Stahlbau*, 1959, *28*, June, pp.156–159. (£2 10*s*.) **[1922**

Hardness testing of thin sheet and tinned sheet. (From German.) WONDRIS, E., and SEUL, V., *Stahl Eisen*, 1960, *80*, 17 March, pp.356–365. (£5 5*s*. 0*d*.) **[1924**

Development of methods of lining open-hearth furnaces in North America. (From German.) HÜTTER, L., *Stahl Eisen*, 1960, **80**, 9 June, pp.788–796. (£6) **[1929**

Effect of deformation and deformation rate on recrystallization of ferritic 25% chromium steel in hot plastic deformation. (From French.) ROSSARD, C., and BLAIN, P., *Rev. Mét. Mém., Sci.* 1960, *57*, March, pp.173–178. (£1 15*s*. 0*d*.) **[1934**

The problem of weighing moving vehicles on a gradient. (From German.) TÖPFER, W., *ETR* Sonderausgabe 11, 1959, Sept., pp.73–78. (£4) **[1945**

Uniform presentation of results of impact tests on rails of varying section: Conclusions on standard requirements. (From German.) JÄNICHE, W. and WINK, W., *Arch. Eisenhütt.*, 1960, *31*, Sept., pp.521–529. (£6 5*s*. 0*d*.) **[1950**

Briquetting iron ores. (From Russian.) RAVICH, B. M., *Metallurg*, 1960, *5*, June, pp.9–11. (£3) **[1955**

Calcination of limestone in a fluidized bed. (From Russian.) DEMENT'EV, V. M. *et al.*, *Metallurg*, 1960, *5*, June, pp.12–14. (£2 10*s*.) **[1956**

Improvements in the photometric determination of silicon. (From Czech.) KONEČNÝ, Z., *Hutn. Listy* (Prague), 1959, *14*, (10), pp.903–904. (£2 15*s*. 0*d*.) **[1961**

Evaluation of replies to a questionnaire on the life of rolls in special steel rolling mills. (From German.) WILHELM, E., *Stahl Eisen*, 1960, *80*, 1 Sept., pp.1207–1211. (£3 5*s*. 0*d*.) **[1963**

The importance of through heating for the construction and operation of pusher furnaces (II). (From German.) WESEMANN, F., *Stahl Eisen*, 1937, *57*, 18 March, pp.296–300. (£3 15*s*. 0*d*.) **[1973b**

Deformation by vibration. (From Russian.) KARNOV, M. YA., and VORONIN, A. A., *Kuznechno-Shtampov* (Moscow), 1960, *2*, March, pp.3–8. (£5 5*s*.) **[1987**

Cause and control of secondary band structure in steel. (From German.) WYSS, U., *Härt-Techn. Mitt.*, 1960, *15*, (1), pp.14–19. (£5 5*s*.) **[1988**

Geometry of the roll pass in the hot pilgering of tubes. (From Russian.) CHEKMAREV, A. P., and CHERNYAVSKII, A. A., *Izvest. VUZ Chern. Met.*, 1959, Nov., pp.47–62. (£5 10*s*. 0*d*.) **[1989**

The change in coercivity during ageing of unalloyed mild steels. (From German.) NACKEN, M., and HELLER, W., *Arch. Eisenhütt.*, 1960, *31*, March, pp.153–160. (£4 5*s*. 0*d*.) **[1990**

Scaling of metals as a function of their pretreatment: (VI). Scaling of plain carbon steel sheets after pickling in different oxide acids. (From German.) PETZOLD, A., *Metall-Reinigung Vorbehandlung*, 1960, *9*, April, pp.53–56. (£2 15*s*. 0*d*.) **[1992**

Chlorination under pressure as second working step in the isolation of oxides in steel. (From German.) BLAZEJAK–DITGES, D., *Radex Rund.*, 1960, Oct., pp.257–261. (£2 10*s*. 0*d*.) **[1993**

A new electrolytic method for carbide research on unalloyed steels. (From German.) HECZKO, T., *Radex Rund.*, 1957, Sept., pp.711–724. (£5 5*s*. 0*d*.) **[2002**

The design of the pilger roll profile for achieving maximum mill output. (From Russian.) PLYATSKOVSKII, O. A., and CHERNYAVSKII, A. A., *Izvest. VUZ Chern. Met.*, 1959, (10), pp.49–56. (£3 5*s*. 0*d*.) **[2004**

Application of chromatography to the analysis of gas mixtures extracted from metals by vacuum melting under reducing conditions. (From French.) BAQUE, C., and CHAMPEIX, L., *Rev. Mét.*, 1960, *57*, Oct., pp.919–923. (£2 15*s*.) **[2010**

The examination of pores in non-metallic protective coatings. (From German.) HORSTMANN, D., *Stahl Eisen*, 1960, *80*, 20 Sept., pp.1348–1349. (£2) **[2034**

ABSTRACTS OF CURRENT LITERATURE AND BOOK NOTICES

Iron and Steel Manufacture and Related Subjects

CONTENTS

Note: The letters *a*, *b*, and *c* refer to the three columns on the page concerned.

	PAGE
Mineral Resources	337a
Ores—Mining and Treatment	337a
Fuels—Preparation, Properties and Uses	338b
Air Pollution and Smoke	339a
Refractory Materials	339a
Iron and Steel, General	339c
Blast-Furnace Practice and Production of Pig Iron	339c
Properties, Treatment and Use of Slags	340a
Direct Processes	340b
Production of Steel	340b
Production of Ferro-Alloys	342c
Foundry Practice	342c
Vacuum Metallurgy	346a
Reheating Furnaces and Soaking Pits	346b
Heat-Treatment and Heat-Treatment Furnaces	346c
Forging, Stamping, Drawing and Pressing	348a
Rolling Mill Practice	349b
Welding and Flame-Cutting	350c
Properties and Tests	351b
Metallography	354c
Corrosion	356a
Analysis	358c
Industrial Uses and Applications	360a
Historical	360b
Economics and Statistics	360c
Miscellaneous	360c

* Abstracts, the reference to which is marked with an asterisk, are or are to be made available as translations.

ABSTRACTS

These abstracts are also available on index cards in advance of publication in the *Journal*, each abstract being classified under the Universal Decimal system (UDC). Details and subscription notes can be obtained from the Secretary, The Iron and Steel Institute.

MINERAL RESOURCES

Principal mineral raw materials for iron and steel industry B. B. Engineer (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 96–113) Occurrence and composition of the principal Indian sources of iron ore, coal, flux, manganese ore, fireclay, chrome ore, magnesite, and dolomite are enumerated.

The geology of the iron ore deposit of Staffhorst–Schwaförden H. Gruss (*Stahl Eisen*, 1960, **80**, Oct. 27, 1449–1452) The deposit was discovered only recently when drilling for oil. It is situated near Bremen in Northern Germany. The deposit is of the sedimentary type, it is a single deposit, about 3·3 m thick. It is estimated to contain 45×10^7 t of iron ore of composition 38%Fe, 5%CaO, 7%SiO_2, and loss on heating (CO_2) 21%.—T.G.

Examples of synsedimentary mineralizations and paradiagenetic formations in the older weathered rock dolomite of Bleiberg-Kreuth O. Schulz (*Berg.-Hütten. Monatsh.*, 1960, **105**, Jan., 1–11) The structures of these deposits are investigated (27 refs).

The changing iron ore industry R. M. Lloyd (*AISI preprint*, 1960, pp.19) A review of resources, exports, and US imports with estimates of future requirements and supplies.

ORES—MINING AND TREATMENT

Iron ore mining in Goa N. Dekowski (*Z. Erzberg. Metallh.*, 1960, **13**, Sept., 441–444) In this instalment the author deals with transportation problems. The ore is exported, e.g. to Japan, which takes as much as all the other countries together, followed by Germany and Italy. The total export amounted to about $2\frac{1}{2} \times 10^6$ t in 1957. As Japan intends to increase her purchases of ore from Goa to three times as much in the next few years the present total output must be doubled. A table is appended listing the analyses of various ores. The lowest Fe content is 57% and the highest 67%.—T.G.

Missouri ore comes in J. D. Idol (*Iron Age*, 1960, **185**, June 30, 115) Development of a high grade magnetite mine at Missouri is described. First samples are being obtained from a shaft at 1680 ft, but two 3000 ft shafts are planned. It is planned to despatch high quality pellets from the site.—D.L.C.P.

Humboldt iron mine opens 650000-ton pellet plant (*Blast Furn. Steel Plant*, 1960, **48**, Oct., 1057–1080) The pelletizing plant, opened in Sept. 1960, produces high-grade iron ore pellets from comparatively low-grade Michigan 'jasper' rock.

The application of a digital computer to the pre-operational problems of programming the extraction and supply of iron ore H. I. A. Archibald (*JISI*, 1961, **197**, April, 309–312) [This issue].

Laboratory investigations into the grinding of reduced jaspilite S. G. Salamy (*BPH Tech. Bull.*, 1960, **4**, March, 2–6) In a laboratory pilot plant, jaspilite is heated in town's gas, haematite is reduced to magnetite, and magnetically concentrated. The results of grinding tests are shown by plotting limiting screen mesh Tyler, against grindability, gm/sec, kWh long tons, and cumulative percentage undersize, respectively. For a given grinding circuit, the reduction increases grinding capacity 2·68 times and there is a similar decrease in the power required.—J.W.J.

Secondary crushing of iron ore by high-frequency currents M. I. Agoshkov and A. S. Voronyuk (*Izvest. Akad. Nauk. Otdel. Tekhn. Met. Toplivo*, 1960, (1), 138–144) The methods of crushing ores with high-frequency currents here explained are: the high frequency magnetic method and the high frequency contact method. Some technical and economic indices are given, for example, the crushing of 1 t iron quartzite with the contact method required 50–60 sec of current supply, and taking into consideration the necessary preparations and the switching on of the generator, about 1·5 min in all, as against 10–15 min needed for mechanical crushing.

A new milling-disc loader and conveyer for heaping and loading H. R. Keller (*Stahl Eisen*, 1960, **80**, Nov. 24, 1801–1803) A new conveyor-belt unit with milling-disc loader is described that can be operated by one man. This unit has proved very useful in handling ores, including fines, coal, coke, limestone, and many other materials.—T.G.

Mesabi scrubber helps heavy-media performance W. R. van Slyke and R. C. Ferguson (*Eng. Min. J.*, 1960, **161**, Sept., 110–114) Tests are described on the scrubbing of intermediate iron ores of the Mesabi range. As a result, 10 scrubbers were installed at the Canisteo Mine, Minnesota, of Cleveland Cliffs Iron Co. Used with heavy media separation, the Fe content of the final concentrates is raised and the SiO_2 content lowered.

Beneficiation and processing of some important raw materials for iron and steel production G. P. Mathur and P. I. A. Narayanan (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 136–142) Beneficiation of iron ore, manganese ore, chromite, fluorspar, and wolfram are discussed, with reference to Indian sources and requirements.

Olenegorsk iron ore concentrates L. Gielicz (*JPRS(NY)*–L–425; *PB* 141321 T; trans. of *Wiadomosci Hutnicze*, 1958, **14**, (6), 182–185; from *US Techn. Trans.*, 1960, **4**, Aug. 10, 176) The Olenegorsk ore is composed mostly of magnetites and to a smaller extent hematite and limonite (in very limited quantities, chiefly in the surface strata). The explored resources of the deposit, down to a depth of 200 m, were estimated at 333×10^6 t. Drillings deeper than 200 m have not yet been executed. The ore is mixed with quartz, and the dia of the magnetite and hematite grains varies from 0·03 to 0·8 mm. The natural ore contains only 30–32% of Fe and 42–46% of SiO_2.—R.S.F.C.

The beneficiation of Hungarian iron-spar L. Visnyovszky and T. Hollo (*Koh. Lapok*, 1960, **93**, March, 110–113) By roasting at 600°C and magnetic separation, the authors produced from the iron spar of Rudabánya, Hungary, a concentrate containing more than 40%Fe. Modifying the method, they also made a concentrate of 90% barytes content from an iron-spar rich in barytes.—P.K.

Investigations into lump-ore reducibility E. Mazanek and W. Markiewicz (*Hutnik*, 1960, **27**, (4), 127–137) The investigations are described and the following results are given; heat penetration into the lumps does not depend on the quality of the ore and cannot be used as a reducibility criterion; internal heat concentration in the lump depends on the size of the lump; porosity is an important factor as it allows penetration by the reducing gas. These results were confirmed by microscopical examination. Reduction starts well inside the lump and is greatly speeded up by porous ore.

Beneficiation of iron ores for use in refining steel melts L. Visnyovszky and T. Hollo (*Koh. Lapok*, 1960, **93**, Jan., 26–31) By means of beneficiation, including magnetic separation, the authors produced from ore-fines of Krivoi Rog and from blast-furnace dust, concentrates of the following composition; 63–67%Fe, 4–8%SiO_2. Mixtures of these concentrates were briquetted and sintered in order to produce suitable ores for use in refining steel melts in OH furnaces.—P.K.

The choice of furnaces and fuel for the magnetizing roasting of Krivoi Rog quartzites K. E. Makhorin and B. P. Bugaenko (*Metallurg.*, 1960, (10), 3–7) Descriptions are given of rotating furnaces and of An'shan-type shaft furnaces. Blast-furnace gas is the fuel and reducing agent for iron ores. When this is not available, natural gas can be used, preferably in rotating furnaces.

The physico-chemical problems of the magnetizing roasting of iron ores J. Trau (*Hutnik*, 1960, **27,** (5), 188–195) The article is concerned with an analysis of existing information on the topic of improving the quality of the ore before further processing. The products to be obtained are magnetite and maghemite (γ-hematite, or γ-Fe_2O_3) by various roasting processes, the latter being preferable technically due to the exothermic reaction. In conclusion, industrial installations are described.

The extraction of vanadium by chlorination and hydrogen reduction J. S. Broadley and C. Tysack (*RDB(C)TN*–118, 1955, March, pp.32; from *Nucl. Sci. Abs.*, 1959, **13,** Nov. 30, 2663) VCl_4 may be almost completely separated from $FeCl_2$, during chlorination by the use of a suitable trap maintained above the boiling point of VCl_4 and below the melting point of $FeCl_2$. Production of powder then proceeds by fractional distillation of the crude VCl_4 and H_2 reduction at 1000°C.

Studies on the extraction of vanadium pentoxide from vanadium bearing titaniferous magnetite ore of Bihar and Orissa M. Roy and P. P. Bhatnagar (*NML Techn. J.*, 1960, **2,** May, 27–31) The ores contain 0·8–1·8%V and 10–20%TiO_2. Salt roasting was studied with reference to particle size, temp., and radical and roasting condition. A recovery of 60% was achieved.

Briquetting of iron-ore fines for use in refining steel melts A. Schedel (*Koh. Lapok*, 1960, **93,** Jan., 32–38) The briquetting of iron-ore fines of Krivoi Rog with cement clinker is described. The cement clinker consisted of calcined red mud and limestone breeze. Before briquetting, manganese sand and/or coke breeze can also be added to the mixture. In this case, the coke consumption of the blast-furnace will decrease with the amount of coke breeze in the ore briquettes. The briquetting method described is advantageous in Hungary, because plenty of suitable red mud and ore fines are there available and the process is cheaper than sintering.—P.K.

Pelletizing of hematite ores C. Mellere (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 124–128) The work carried out by Istituto Siderurgico FINSIDER, on the laboratory, semi-industrial, and industrial pilot plant scale in the pelletizing of Elba Isle hematite ores is described.

Studies in the sintering permeability and pellet strength of Australian hematite ores W. Callender (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 114–123) The experimental procedure adopted in investigations at the Central Research Laboratories of Broken Hill Proprietary Co. Ltd, to establish the main sources of resistance in sinter beds containing high grade hematite ores is described, and the results are related to the 'balling' characteristics of different ore mixes.

Making and properties of mixed magnetite-hematite pellets A. Palazzi and A. Colombo (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 130–135) A description of work carried out by Instituto Siderurgico FINSIDER on pelletizing trials with increasing additions of hematite ores and firing at various temps. With 50% hematite, strength after firing remains high and reducibility is not altered. The mixed 50% hematite pellets have a strength comparable to that of magnetite pellets.

Sinter plant assessment trials at Guest Keen Iron and Steel Co. Ltd J. McKelvie and G. Wilson (*JISI*, 1961, **197,** April, 313–318) [This issue].

Study of the effect of gas vibrations on the reduction behaviour of iron oxides H. Schenck and J. Cloth (*Stahl Eisen*, 1960, **80,** Oct. 27, 1453–1457) Reduction trials on specially prepared samples of iron ore are described which were carried out in the presence of vibrations of various frequencies. The vibrations were created in the surrounding gas phase and led to a rapid equalization of the gas composition above the ore sample. In finely porous ore, low and ultrasonic vibrations gave an acceleration of the reduction rate, with ore of larger pore size, low, and medium frequencies showed the greatest effect, ultra-sound being absorbed in the outer zones of the samples. The iron formed in the reduction agglomerates in a peculiar way, this is attributed to a reduction in the decomposition rate of the CO (13 refs).—T.G.

Magnetic roasting of Lisakovka ores in a pseudo-finished bed V. V. Chukin, V. Ya. Miller, S. D. Toporkov, V. G. Karelin, V. N. Bogoslovskii, and L. I. Leont'ev (*Stal'*, 1960, (11), 965–971) Laboratory scale and model studies were carried out and an experimental furnace constructed. Rapid heating to 700–900°C in a weakly reducing atmosphere of waste gases (3%Co) gave a good product with 50–60% reduction to Fe_3O_4 using cheap fuel, the drying process was included simultaneously and not carried out in advance.

Three ore reducing processes S. Eketorp (*Tek. Tids.*, 1960, **90,** April 8, 377–382) The processes described are the magnetizing reduction of Fe_2O_3 to Fe_3O_4 at 700°C, decarburizing granulated pig iron with ore concentrates at 1100°C, and the reduction of ore in an iron or steel bath at 1400–1600°C.

The role of mixing methods and mixer designs in the field of iron ore sintering G. Brandes and H. Rausch (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 176–185) A description is given of the types of mixer and granulating equipment in present use, and mixing and re-rolling techniques, and the influence of the mixing process on sintering is demonstrated.

Latest experience in the use of equipment at sinter plants D. P. Pritykin (*Metallurg.*, 1960, (10), 7–11) Descriptions are given of sintering machines, exhaust fans, coke crushers; slat conveyors, vibration feeders, a centrifuge-type filtration device with a vacuum pump, and a wagon with a bunker and screen for distributing sinter samples. Automation is discussed.

Laboratory researches on self-fluxing sinter. I. On the effect of the addition of limestone on the reducibility of sinter S. Watanabe and T. Matsuoka (*Sumi Met.*, 1959, **11,** Oct., 261–265) Reduction tests were made on 11 sinters, of coke content 2–5% and limestone 0–15%. Addition of limestone maintains reducibility when more coke is used. With 5% limestone, fayalite disappears and reducibility is improved; larger additions have no effect on reducibility. Limestone weakens the sinter, but this effect is countered by its lessened disintegration during reduction.—K.E.J.

Automation of the returns cycle in a sintering machine V. F. Pochta (*Stal'*, 1960, (11), 963–965) Manual control was not satisfactory as the discharge on to the returns belt was often hot enough to destroy the conveyor. An automatic system is described with control of the cooling and discharge systems.

Trouble spots in sintering plants G. R. Baer and R. E. Powers (*Iron Steel Eng.*, 1960, **37,** July, 93–101) The paper deals primarily with trouble encountered in plants of the travelling grate type, and covers materials handling, equipment, and operation.

FUELS—PREPARATION, PROPERTIES AND USES

The problem of the supply of coal for the new steel plants N. N. Das Gupta, K. V. Shrikhande, and V. V. Rao (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 467–482) A detailed account, with a full report of results, of investigations on the use of sub-standard Indian coals for coking, in blends with normal coking coals.

Some aspects of preparation of coal for coking (II) A. Lahiri, N. N. Das Gupta, and T. N. Basu (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 280–291) Special properties of Indian coals and the specific systems of coal preparation proposed to suit these properties are discussed.

Mass handling of materials S. K. Majumdar and A. Lahiri (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 456–460) Transportation, storage, and handling methods generally employed in coal based industries in India are outlined, with special reference to the proposed Central Washeries of India.

Principal aspects of investigations into fluidized carbonisation undertaken at the Marienau Experimental Station J. Geoffroy and C. Meltzheim (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 144–150) A description is given of the experiments carried out with the pilot fluidizer set up by CERCHAR and IRSID on the application of fluidization to the carbonization of coal fines.

Correlations among some physical properties of coke—a statistical study N. C. Sinha, J. M. Sanyal, N. N. Das Gupta, and A. Lahiri (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 461–466) Shatter, Micum, Haven, and B.S. abrasion values are correlated.

The effect of the mechanical resistance of coke on its specific consumption at the Hunedoara Siderurgical Combine S. Popa (*Met. si Constr. Masini*, 1960, **12,** (6), 542–543) By mechanical resistance is understood the capacity of the coke to withstand weight and crushing by impact or friction. This characteristic conditions the behaviour of the coke in the furnace. It has been established that there exists an inverse relation between the specific consumption of coke and its mechanical resistance.

Assessment of hard coke requirement in India A. Lahiri, A. Ghosal, and N. C. Sinha (*Indian Construction News, Special No.*, 1958, **7,** Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 370–374) Requirements are examined in the light of the Five Year Plans, with reference to steel plants and to foundries, chemical, and other industries.

Production experience at Port Kembla with coke made from 'fine grind' oiled coal charges W. R. Gadsden (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 168–175) The characteristics of the coking coal and coke used at Port Kembla are reviewed, trials on coal grinding and blending are described, and a series of trials on oiling of the coal charges are described and the results discussed.

Laboratory coking tests T. G. Callcott, P. L. W. Muir, and J. A. Innes (*BHP Tech. Bull.*, 1960, **4,** March, 7–15) Laboratory carbonizing tests help in the selection of coals for coking by comparing the properties of local and imported coals. Volume change and plasticity during coking are important. Tests reported are: proximate analysis, crucible swelling test, Gray–King assay showing yield of by-products and type of coke, Audibert-Arnu dilatometer for volume changes during heating, Gieseler Plastometer measuring fluidity during the swelling state (350–500°C) by means of a rotating paddle and a penetration plastometer indicating plastic properties near the coke forming stage. These tests on a particular coal can be correlated with the properties of the coke produced, especially the strength.

High temperature testing of coke and synthetic agglomerates P. J. Zorena, M. O. Holowaty, and C. M. Squarey (*Blast Furn. Steel Plant*, 1960, **48,** May, 443–451) A high-temp. test and by Inland Steel Co. to predict the behaviour in the high-temp. zone of the blast-furnace of coke and pellets is described, with details of the equipment and results.

Testing methods for the determination of the reactivity of coke G. W. Lask (*Stahl Eisen*, 1960, **80,** Nov. 24, 1798–1801) The author reviews published information on testing methods for the determination of the reactivity of coke and discusses the merits of the individual methods. Although good progress has been made in the last few years, no method exists so far that could be accepted generally and without reserve.—T.G.

The size requirements of blast furnace coke (I) N. N. Das Gupta and A. Lahiri (*Symposium on Iron and Steel Industrykin India*, 1959, Feb., 274–279) The influence of various factors on coke size is discussed. It is concluded that the result of adopting certain measures, proposed by the Central Fuel Research Institute, including the additions of high-temp. coke breeze to the coking coal mixture, suitable blending, coal washing, and crushing procedures, and a quicker heating rate, would result in the production of a higher proportion of intermediate sizes (11 refs).

New methods for testing blast-furnace coke W. Zimmer and W. Neukirch (*Neue Hütte*, 1960, **5,** Oct., 585–590) The authors review the various methods used for testing blast-furnace coke and discuss Graf's method and the

significance of the Graf coefficient in detail. They suggest a simplification of Graf's method, and introduce the tangent of the line through the centre of gravity of the measured values. It is pointed out that all values independent of the method by which they are obtained must still be brought into correlation with local blast-furnace conditions (16 refs).—T.G.

Flames and furnaces: combustion of pulverized fuel M. W. Thring (*Iron Steel*, 1960, **33**, Aug., 423–428) The development of the pulverized fuel chamber is discussed and the mechanism of the reaction system investigated. Factors influencing burning times and flame speed are examined.

AIR POLLUTION AND SMOKE

Electro-precipitators in the European iron and steel industry E. Bruederle, C. Scheidel, and H. Werner (*Blast Furn. Steel Plant*, 1960, **48**, Oct., 1031–1037) An account of the principles of electrostatic dust precipitation, and advances in design and in the characteristic features of electro-precipitator equipment in the European iron and steel industry. A number of illustrations are given of equipment of Lurgi Apparatebau G.m.b.H.

Dust abatement problems in the foundry industry V. Klinge (*Giesserei*, 1960, **47**, Sept. 22, 526–530) After a general discussion of the problem, with particular attention to sand coveying and preparation equipment as the main sources of dust, various systems for removing dust are described and compared.

REFRACTORY MATERIALS

The genesis of the dense magnesite of Kraubath K. Vohryzka (*Berg.-Hütten Monatsh.*, 1960, **105**, Jan., 12–16) A discussion, with a review of the literature (33 refs).

Refractory materials for the iron and steel industry J. M. Palacios Repáraz (*Dyna*, 1960, **35**, Oct., 757–765) The properties and manufacture of basic and neutral bricks are discussed.—P.S.

Up-to-date basic-refractory bricks J. Sövegjártó (*Koh. Lapok*, 1960, **93**, Feb., 68–72; March, 114–117) The production, chemical composition, mechanical properties, and use in OH furnaces of basic-refractory bricks are described. Reference is also made to the recently introduced metal-clad basic-refractory bricks, sometimes also containing metal inserts.—P.K.

Role of refractories in iron and steel foundries P. C. Sen, M. R. K. Rao, and H. V. Bhaskar Rao (*Indian Construction News*, 1958, **7**, Nov., Special No.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8,, 363–369) The limitations of conventional acid refractories are examined, and the use of Indian refractory materials which are in plentiful supply is advocated (11 refs).

Flames and furnaces M. W. Thring (*Iron Steel*, 1960, **33**, June, 331–337) The author describes the science of furnace construction dealing with silica bricks, basic refractories, miscellaneous refractories, refractory cements, ramming mixes, and castables and refractory insulation.

Advances in the refractories industry in China K. Shaw (*Iron Steel*, 1960, **33**, June, 314–315) Details of the production and types of refractory used in present-day China are given China has no deposits of chromite but ample reserves of high alumina materials and magnesite. Spinel bonded magnesite has been developed to replace magnesite–chromite in OH roofs. Tables give properties of Chinese high alumina brick, Chinese spinel bonded magnesite bricks, and comparative wear of roof-brick in China. Silica brick refractory development is also dealt with.

The compaction of magnesite mixes and the production of dense magnesite refractories I. S. Kaynarskii and N. D. Nazarenko (*Ogneupory*, 1955, **20**, (7), 291; *SLA* 60–13962; from *US Tech. Trans.*, 1960, **3**, June 24, 738) No abstract.—S.H.-S.

The properties of refractories made from magnesite and high-alumina raw materials V. A. Rybnikov (*Ogneupory*, 1956, **21**, (1), 37 ff; *SLA* 60–13963; from *US Tech. Trans.*, 1960, **3**, June 24, 801) No abstract.—S.H.-S.

Materials of high refractoriness for lining furnaces N. I. Voronin and E. C. Podzolova (*Ogneupory*, 1947, **12**, 206 ff; *SLA* 60–13956; from *US Tech. Trans.*, 1960, **3**, June 24, 801) Abridged; no abstract.—S.H.-S.

The service of magnesite–chrome refractories in the roof of a high-temperature tunnel kiln V. P. Starun and M. I. Kolesnik (*Ogneupory*, 1958, **23**, (6), 257; *SLA* 60–13981; from *US Tech. Trans.*, 1960, **3**, June 24, 801) The replacement of high-alumina refractories in the roofs of tunnel kilns by magnesite–chrome overcame the problem of firing a magnesite–chrome refractories at 1700–1750°, and enabled the mass production of magnesite–chrome roof bricks of high density (periclase–spinel type) from hard-firing Kimpersaisk chromite for converters with oxygen blowing and for the ports of open-hearth furnaces.

The problem of producing highly aluminous refractories from diaspore concentrate Ya. A. Orlovskii and D. S. Rutman (*Ogneupory*, 1951, **16**, 435 ff; *SLA* 60–13950; from *US Tech. Trans.*, 1960, **3**, June 24, 800) No abstract.

The quality of refractories for the feeders has improved V. B. Bur'yan and N. K. Kiselev (*Sikloi Keramika*, USSR, 1958, **15**, (1), 28; *SLA* 60–13996; from *US Tech. Trans.*, 1960, **3**, June 24, 797) No abstract.—S.H.-S.

A physicochemical method for increasing the density of refractories made of lean mixes I. S. Kaynarskii (*Ogneupory*, 1951, **16**, 60; *SLA* 60–13943; from *US Tech. Trans.*, 1960, **3**, June 24, 798) No abstract.—S.H.-S.

The influence of mineralizers on the formation of a forsterite bond in magnesite mixes A. A. Pirogov (*Ogneupory*, 1955, **20**, pp.263 ff; *SLA* 60–13960; from *US Tech. Trans.*, 1960, **3**, June 24, 800) No abstract.—S.H.-S.

The testing of silica bricks with an MgO–MnO bond in the roofs of O.H. furnaces A. P. Klyucherov and Zh. A. Vydrina (*Ogneupory*, 1958, **23**, (10), 476–478; *SLA* 60–13975; from *US Tech. Trans.*, 1960, **3**, June 24, 798) Test showed that this type of brick is more sensitive to overheating and assumes a position in quality intermediate between VPD and normal silica bricks.—S.H.-S.

Constitution, properties and uses of chrome–magnesite and magnesite-chrome bricks in open-hearth furnaces E. Perez Blanco (*Inst. Hierro Acero*, 1960, **13**, July–Sept., 677–700) The requirements of the raw materials used for the manufacture of chrome–magnesite bricks are discussed. The properties of the bricks and their possible damage in service by bursting, liquid movement, and zone formation are considered and amplified by a detailed study of a representative brick removed from a 300 t OH furnace. A comparative study of national and foreign bricks, using data supplied by the manufacturers and by further tests, is reported. From this study, tentative standards for the raw materials and the manufactured bricks are suggested (32 refs).—P.S.

Volume and structural changes associated with phase conversions during the firing of mullite: corundum refractories D. N. Polyboyarinov, R. Ya. Popol'skii, and Z. K. Sterlyadkina (*Ogneupory*, 1955, **20**, 315 ff; *SLA* 60–13968; from *US Tech. Trans.*, 1960, **3**, June, 24 800–801) The dynamics of volume changes associated with the reaction of secondary mullite formation were classified, and the effect of basic factors on the process was defined. Five methods to reduce or eliminate rise of temp. and to increase the capacity of the body to undergo further vitrification in the final stage of firing, in practice, are indicated.

A standard-type apparatus for the tests of refractories for deformation-under-load at high temperatures E. K. Keler (*Ogneupory*, 1952, **17**, 169 ff; *SLA* 60–13955; from *US Tech. Trans.*, 1960, **3**, June 24, 798) No abstract.

A micro-method for determining the melting point of highly refractory materials L. Ya. Markovskii, N. V. Vekshina, and R. A. Shtrikhman (*Ogneupory*, 1957, **22**, 42 ff; *SLA* 60–13966; from *US Tech. Trans.*, 1960, **3**, June 24, 799) A simple method for measuring the melting point of refractory substances is proposed. The method is tested using a number of substances with known melting points. A new value (2280°C) for the melting point of chromium diboride is obtained.—S.H.-S.

Measurement of elastic recovery on pressing magnesite bodies E. V. Ivanov, F. I. Chuprinin, and Ya. M. Minskii (*Ogneupory*, 1957, **22**, 120; *SLA* 60–13964; from *US Tech. Trans.*, 1960, **3**, June 24, 798) No abstract.—S.H.-S.

IRON AND STEEL—GENERAL

Recent trends in iron and steel technology B. R. Nijhawan (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 292–307) A general review of iron- and steelmaking advances in various parts of the world. Considerable space is given to Soviet blast-furnace and steelmaking technology; other subjects discussed include progress in the use of pneumatic processes, the low-shaft blast-furnace, and direct reduction; and a final section is devoted to a description of the Lubatti process for smelting iron ore fines in open electric furnaces.

Some recent trends on iron and steel research and control methods G. P. Chatterjee (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 316–321) Investigations in blast-furnace, steelmaking, and rolling mill practice, and in analytical techniques are enumerated and discussed briefly.

The new iron works Bremen of Klöckner-Werke AG in the coastal district near the North Sea W. Heemeyer and W. Asbeck (*Stahl Eisen*, 1960, **80**, Oct. 27, 1443–1448) Layout and construction of the new ironworks near Bremen—the first built in Germany for more than 20 years—is described. The works are planned for a production of 5×10^6 t of iron. Steelworks and rolling mills are being included.—T.G.

Great Lakes Steel Corporation: a Division of National Steel Corporation C. Longenecker (*Blast Furn. Steel Plant*, 1960, **48**, Aug., 781–819) The coke ovens, iron and steelmaking plants, blooming, slabbing bar, and strip mills, materials handling, and services are described.

Tasks and requirements of technical research at the commencement of the 1960s E. Velander (*Jernkont. Ann.*, 1960, **144**, (6), 401–431; discussion 418–431) A general account of planning, organization, and the possibilities of co-operation.

Recent trends in iron and steel making in Japan K. Wada (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 435–444) A review of the position in 1958, including blast-furnace and ore beneficiation practice, experimental work on the low-shaft blast-furnace, the use of LD converters, and the manufacture of ferroalloys.

TMP. An account of Tata Steel's expansion under the second Five Year Plan (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 493–515) A detailed account of programmes in the iron and steelmaking and ancillary sections.

Pig iron production and steel making G. Bulle (*VDIZ*, 1960, **102**, Nov. 1, 1487–1492) A review of progress made in pig iron production and steel during the last year. The review is mainly concerned with German practice and outputs, but those of other countries are also mentioned (65 refs).—T.G.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG-IRON

Australia's biggest blast furnace (*Brit. Steel*, 1960, **26**, March, 99–101) A description of the No.4 blast-furnace at the Port Kembla works of B.H.P., built by Ashmore, Benson, Pease and Co. Ltd.

The question of blast furnace profiling W. Zólkowski (*Hutnik*, 1960, **27**, (5), 168–172) The author deals at length with the various theories of furnace profiling, pointing out at the same time that rapid and profound corrosion takes place in practice. The only conclusion drawn in the article is that thick walls are positively superior to thin walls.

Prefabricated blast furnace moved 87 feet 6 inches to replace old furnace (*Blast Furn. Steel Plant*, 1960, **48**, Oct., 1038) A note on the moving into position of a prefabricated shell and other sections at the works of Granite City Steel Co.

Folding scaffold is used in blast furnace overhaul (*Steel*, 1960, **147**, Aug. 8, 96) A folding scaffold in use by Bethlemen Steel Co. at its Sparrow Point (Md) plant, which will carry 30 workmen into the stack for lining removal and

shell inspection and serve as a working surface for brick-layers relining the furnace is described and its operation shown.—S.H.-S.

Nuclear energy in iron- and steelmaking P. Bergognon, R. Bourion, and R. Gibrat (*A/Conf.* 15/P/1136, pp.24; from *Nucl. Sci. Abs.*, 1959, **13**, April 30, 906) [In French] Energy requirements and consumption are surveyed with a view to the use of a nuclear reactor to supply some of this energy. An example is considered of the use of a nuclear reactor to preheat the blast of a blast-furnace.

Practical applications of a thermochemical model of a blast furnace H. S. Turner (*Reg. Tech. Meet. AISI*, 1960, Nov. 16, pp.21, preprint) A thermochemical model in terms of an enthalpy equation is used to predict operational factors in the blast-furnace and compared with trial runs. Change in burden and blast are considered and the use of the method in setting up operating schedules is discussed.

Developments in blast furnace practice T. P. Colclough (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 222–228) The influence of such factors as hearth diameter, improved burden distribution, increased proportions of sinter, particularly self-fluxing sinter, high top pressures, and steam and oxygen additions on productivity and coke rate is considered.

On the theory of hot-cooling installations with forced circulation F. Bukau (*Neue Hütte*, 1960, **5**, Oct., 618–622) The author defines the limits between natural convection cooling and forced circulation cooling for hot-cooling systems and discusses the theory of forced circulation of the cooling water with special emphasis on cavitation. A nomogram shows the correlation between cavitation occurrence and pressure in the system.—T.G.

Application and heat-economy importance of hot-cooling of the blast furnaces in the integrated iron and steel works. I. V. Stalin F. Bukau (*Neue Hütte*, 1960, **5**, Oct., 622–626) The I.V. Stalin integrated iron and steelworks are at Stalinstadt in Eastern Germany situated between the rivers Oder and Spree and connected by canals with both rivers. Owing to the high water consumption and the limited amount of water available, hot cooling of the blast furnaces is imperative. It saves about a third of the cooling-water consumption and the savings in expenditure are so great that the capital outlay is recovered in about two years (15 refs).—T.G.

Low shaft furnace smelting of pig iron in India A. B. Chatterjea and B. R. Nijhawan (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 244–251) In view of the comparative shortage of coking coal and good supplies of non-coking coal and lignite in India, it is considered that the low shaft furnace process may be economical. Possible locations of such plants in India are considered.

Technological aspects of low shaft furnace process A. B. Chatterjea (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 252–258) Furnace height, output, fuel consumption, and reduction equilibrium, desulphurization, reduction characteristics, and blast temperature, and its enrichment with O_2 are considered (12 refs).

PROPERTIES, TREATMENT AND USE OF SLAGS

Dolomite as a flux for high-alumina blast furnace slags T. V. Mannarswamy, V. G. Paranjpe, and S. Visvanathan (*Symposium of Iron and Steel Industry in India*, 1959, Feb., 308–314) Trials described indicate that the replacement of up to 30% limestone by dolomite gave improved results in respect of the Si and S contents of the iron, and of slag characteristics.

Viscosity of the synthetic slags of the calcium fluoride–calcium oxide–silica system with addition of 5% alumina Li Tao-chao and L. M. Tsylov (*Izvest. Akad. Nauk. Otdel. Tekhn. Met. Toplivo*, 1960, (1), 21–29) The investigations of these slags were carried out in accordance with the conditions of the initial and final slags when smelting Bayun' ores. It was found that CaF_2 is assimilated with difficulty in acid and basic slags. At temp. above 1400°C, with an increase in the CaF_2 concentration the viscosity of the slags decreases while it increases below this temp. This increase in the viscosity at crystallization temp. of CaO and CaF_2 is explained by the precipitation of the crystals of the silicates and fluorides.

DIRECT PROCESSES

Direct iron ore reduction for Asia H. A. Havemann (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 260–272) The main direct reduction processes in commercial use are outlined and assessed, and the article ends with a brief reference to the possibilities of direct reduction processes in Asia. It is concluded that the HyL processes would be most suitable for Asiatic conditions (122 refs).

The application of the metallothermal method to the production of iron and steel A. Wimmer (*Stahl Eisen*, 1960, **80**, Oct. 27, 1469–1477) The fundamentals and application of the metallothermal process or iron and steel production are considered and a two-stage process suggested. Using low-grade carbonaceous materials and electric current for the preparation of the burden, the direct production of iron from high-grade ore is possible without the employment of coke as a heating or reduction agent.—T.G.

The rotor steel works of Ilsedor Hütte W. Köhler (**Klepzig Fachberichte*, 341–343) The recently erected rotor plant incorporates equipment for rapid changeover for repairs. The rotor rests on a combined cradle and turntable, and can be transferred to an adjacent stand for stripping and relining.

Kaldo gets big test in France G. J. McManus (*Iron Age*, 1960, **185**, June 30, 111) First operating results from the two 110-t Stora–Kaldo O_2 steelmaking vessels at Sollac, France are reported. Performance is satisfactory. The deep drawing steel is of good quality. Ingot yields average 90%; reaction rates are high.

PRODUCTION OF STEEL

The future of the German scrap supply H. P. Killing (*Stahl Eisen*, 1960, **80**, Nov. 10, 1700–1710) This is a comprehensive analysis of the various sources of scrap in Gremany at present and in the future. American investigations of the problem are reviewed. It is concluded that the prospects of scrap supply are bright—or at least brighter—for the future. It is interesting to note that the author expects that the amounts, relative and absolute, of recirculation scrap will tend to increase.—T.G.

Iron pretreatment research J. A. Charles (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 152–159) An account of research carried out by British Oxygen Research and Development Ltd, on the use of O_2 in pretreatment; the paper deals with the investigation of ladle treatment methods with normal methods of adding slag-making material; the tower pretreatment process; and the powder pretreatment process.

Comparative costs of iron pretreatment A. N. Whiting (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 160–167) The methods on which costs are assessed are: the active mixer, rotary furnace, acid duplex, tower, blast-furnace runner, and ladle processes.

Oxygen by the ton (*Commonw. Eng.*, 1960, **48**, Aug. 5, 46–48) The advantages and increased use of O_2 in steelmaking throughout the world is described with reference to various development schemes in Britain and Australia.

The use of an electromagnet for removing Babbitt from steel swarf V. I. Skripchenko (*Lit. Proizv.*, 1960, (10), 45) Type B-83 Babbitt (Sn–Sb–Cu) is used for fluid-friction bearings. A diagram is shown of the electromagnet used under industrial conditions for the removal of Babbitt from steel swarf. Dimensions are given and the method described. The electromagnet has been in successful operation for over a year.

The carbon–oxygen equilibria in liquid iron T. Fuwa and J. Chipman (*Trans. Met. Soc. AIME*, 1960, **218**, Oct., 887–891) Published equilibrium data on reactions of gases with C and O_2 dissolved in liquid iron are reviewed, and a source of error in O_2 analysis of graphitic samples is revealed, this is the adsorption of O_2 and H_2O. New experimental results on the O_2 content of high-C iron in equilibrium with CO indicate that the activity coefficient of O_2 is decreased by C additions, and that the [C] [O] product decreases slightly with increasing C content (18 refs).

The new integrated iron and steel works Bremen of Klöckner–Werke AG near the North Sea coast W. Heemeyer and W. Asbeck (*Stahl Eisen*, 1960, **80**, Nov. 10, 1711–1727) In this part of the report the OH steelworks is described; three furnaces are in operation and two in course of erection. This is followed by a description of the hot and cold rolling mills, including wide strip rolling. The report ends with details of the auxiliary equipment and plant.—T.G.

Canadian Steel Wheel Limited (*Official opening of Canadian Steel Wheel Limited, Information Kit*, 1959, June 11, pp.72) A guide to the plant and much general information are presented.

Oxygen process for iron and steel making. I K. Morinaga (*Tetsu to Hagane*, 1960, **46**, June, 683–700) A review of British, American, Continental, and Russian practice with the blast-furnace, OH, LD, Kaldo, and other processes.

Pneumatic processes in steel production G. Répási (*Koh. Lapok*, 1960, **93**, Jan., 12–16, Feb., 60–65) The paper is a comprehensive and critical review of the various pneumatic processes in steelmaking, and it is based on the proceedings of the Metallurgical Conference in Luxembourg, 1958.—F.K.

Metallurgical aspects of the basic oxygen process L. W. Frech (*Blast Furn. Steel Plant*, 1960, **48**, May, 452–455) Temp. and slag control, type of products made, and composition of steel in the process as worked at the Aliquippa works of Jones and Laughlin are described.

Hydraulic drive for steel converters M. Sanson (*Mét. Constr. Mécan.*, 1960, **92**, Sept., 647–648, 651–653) A study of work undertaken by the Morane Cie in the field of converter mechanisms with hydraulic drive: valve-gears, hydraulic servo-motor systems, and fully interlocked control systems; with further reference to the construction of certain types under licence in Germany, England, Spain, and Italy.

Metallurgy, heat balance, and economy of the converter processes T. Kootz (*Bergakademie*, 1960, **12**, Sept., 484–491) The author compares the metallurgical aspects of steelmaking in OH furnaces with those in converters. As nowadays the quality of the steel is almost independent of the process of production, the choice of the steelmaking process is now mainly affected by the availability of the pig iron, scrap steel or ore, and by the costs. The individual factors particularly the heat balance, are discussed in detail (19 refs).—T.G.

The pre-refining of blast-furnace iron ore and development of the Brymbo oxygen/electric steelmaking process E. Davies (*JISI*, 1961, **197**, April, 271–282) [This issue].

Oxygen boost to increase steel output (*Steel*, 1960, **147**, July 18, 94–96) Increased production of oxygen for OH furnaces to increase steel output and to permit blast enrichment in the Wierton Steel Co.'s Wierton, W. Va. blast-furnaces is presented.—S.H.-S.

Use of oxygen lances and basic brick in open hearth furnace roofs. I H. A. Parker and P. Schane jun. (*Ind. Heat.*, 1960, **27**, June, 1213–1228, 1260) After a consideration of the oxygen requirements of the OH, an account is given of the development of oxygen blowing. Full details are given of practice in which single or multiple roof lances are used in the bath throughout the whole working of hot-metal heats. The water-cooled lances are described. The practice is used on 73 of the 256 furnaces of US Steel Corp. Carbon drops of 0·75–0·90% per h are obtained, heat times are shortened by 10–25%, and fuel consumption is reduced by 18–35%.—K.E.J.

Accelerating combustion in the open hearth furnace by auxiliary jets H. Hasimoto (*Tetsu to Hagane*, 1960, **46**, April, 480–483) Jets from the roof or side walls create eddy spots and,

hence temporary walls which are aerodynamic, controllable and free from wear. The effectiveness depends on the momentum, not the size of the jet, and the composition (air, O_2, or steam) and temp. are of no significance.

On the representation in the ternary diagram of the equilibrium in the distribution of the sulphur between slag and metal in the production of steel in the O.H. furnace G. Violi (*Inst. Chim. Applicata, Università di Trieste*, 1958, (5), pp.15) The OH furnace is to a certain extent self-regulating as regards sulphur equilibrium and the range of possible slag compositions. As the increase in basicity is accompanied generally by an increase in FeO the series of distribution ratios of the sulphur effectively obtainable is rather restricted. This limits the possibilities open to the operator. In this case, also, the importance of carbon reaction is evident in refining the steel as it is this which selects the slag compatible with the prescribed carbon content.

Scrap and coke practice T. Kishino, I. Wakai, Y. Noguchi, and Y. Kawabata (*Nisshin Seiko Giho*, 1959, Dec., 3–10) The operating methods and results obtained with low-carbon rimming steel are described. A method of charging scrap and coke breeze into flame-enriched oxygen steelmaking furnaces is described. At 18 kg/t heat time was not prolonged in relation to the increased amount of coke breeze charged. The gradient of the heat time curve became very small. The pig ratio decreased linearly to 0% at 2000 kg of coke breeze. One t of coke breeze replaced 8·1 t of pig iron which was equivalent to a recovery of about 50% of the coke breeze charged.

Ford reveals new technique in OH steelmaking with oxygen (*Iron Steel Eng.*, 1960, **37** June, 145) The method, in which burnt lime is substituted for limestone and an oxygen-fuel lance of special design is used, has increased substantially the output of 200 and 400 t furnaces. Two lances per furnace are employed.

Heat consumption in open hearth steel production F. Sulcz (*Koh. Lapok*, 1960, **93**, May, 200–206; June 274–278) The relation of heat consumption to the charging time and meltdown carbon, to the difference between meltdown and final carbon, and between meltdown and final sulphur contents, finally to the amount and pouring-in time of hot metal has been determined by calculating a partial regression equation from the operation data of two Hungarian OH furnaces. An increasing charging time and a greater difference between melt-down and final carbon, and between meltdown and final sulphur contents have increased, but a higher melt-down carbon itself has decreased the heat consumption. The greatest influence, about 55–65% of the heat consumption has been exerted by the charging time. The effect of other factors has been as follows: melt-down carbon 8–20%, difference between melt-down and final carbon contents 12–30%, and between melt-down and final sulphur contents 8–10%. For each furnace, there has been an optimum amount of hot metal, as well as an optimum pouring-in time, to give the minimum heat consumption.—P.K.

Influence on heat recovery in the open hearth furnace of the humidity of combustion air A. Ramacciotti (*Met. Ital.*, 1960, **52**, July, 423 433) [In Italian] This study shown that variations in humidity of the combustion air have unforeseen effects on the efficiency and temp. of the regenerators. As the H_2O content of the air increases its capacity to absorb heat from the brick walls also increases, resulting in improved efficiency of the regenerator and lower brick surface temp. Control of the humidity of the combustion air is recommended on the assumption that these experimental findings are confirmed.

Progress report on carbon bottoms for open hearth furnaces J. E. Smith (*Ind. Heat.*, 1960, **27**, June, 1276–1278) For lengths of time corresponding with 1900 heats tapped, a 9 min/day heat delay time has been maintained on a carbon sub-hearth. This time can be maintained by replacing any part of the working surface without increasing rebuilding time. After 1268 heats, carbon blocks and joints looked new. Temp. at the top of and below the hearth during tapping are examined.

Technical and economic indices of steel production in open hearth and electric furnaces using silico-chromium G. A. Khasin and V. N. Davidyuk (*Stal'*, 1960, (9), 808) A note from Zlatoust and Chelyabinsk Research Institute. Storage difficulties are mentioned.

Open hearth checkers cleaned effectively with high pressure water system at Great Lakes Steel Plant (*Ind. Heat.*, 1960, **27**, May, 1056–1058) The need for any manual cleaning is virtually eliminated. A portable trailer-mounted pumping rig has a plunger pump connected to a 40 hp motor reducer; the 25 ft lance delivers water at 970 psi to a multi-nozzle orifice. Both chequer banks are cleaned in one 8-h shift.—K.E.J.

The use of nickel oxide instead of metallic nickel in steelmaking G. A. Khasin and V. N. Davidyuk (*Stal'*, 1960, (9), 808) A note from Zlatoust. Nickel oxide could be used with a small increase in pig iron consumption, increased use of power and Fe–Si, and increased heat time (in the electric furnace). However savings were still considerable.

The use of nickel oxide for producing chromium–nickel steels in large open hearth furnaces B. G. Petukhov and P. K. Morokov (*Stal'*, 1960, (10), 892–896) It is shown that NiO can be substituted for metallic Ni in the OH furnace without appreciable change in the process or product. Details of many trial heats are given. Pelletized oxide is used as the powder may be carried away in the gases. The slag contained 0·2%Ni.

Kinetics of decarburization in molten steel. V. The mechanism of decarburization T. Fujii (*Tetsu to Hagane*, 1960, **46**, April, 473–480) Results from work in HF and OH furnaces are summarized. In the OH furnace the rate-determining steps are movement of O_2 through the boundary layer between slag and steel, and diffusion and escape of CO through the boundary layer between steel and the gas phase of CO bubbles or creviced in the hearth (15 refs).—K.E.J.

Modification of the process of valve changeover in open hearth furnaces fired by producer gas. I. Gas explosions in the flue system during the reversal process H. Schicke and H. Gauter (*Neue Hütte*, 1960, **5**, Aug., 464–473) An investigation of the causes of the frequent gas explosions which occurred in the system during reversal, by analysing the mixture proportions of gas, air, and waste gas showed that an explosive mixture was formed at each change, which usually, but not always, burned during mixing without an explosion. Possible methods of preventing explosion are examined.

Electrical precipitation for open hearth furnaces (*Turnbridge News*, 1959, **4**, Autumn, 4–5) This note describes electrical precipitators to be installed by W. C. Holmes & Co. Ltd, and the Pittsburgh Works of Jones and Laughlin Steel Corporation and at Cornigliano SpA at Genoa for air pollution control of OH furnace stacks.

Scrap melting in electrics speeded by oxy-gas burners G. W. Hinds and A. L. Hodge (*Steel*, 1960, **146**, April 18, 144–146) The use of oxy-gas burners in electrode steelmelting furnaces is described. This practice reduces melting times and power consumption. It is particularly useful where there is excess finishing capacity or difficulty with power supply. In particular the burners are valuable in melting scrap around the walls of the furnace. It is not thought that they will affect wall-wear or electrode life. The burners may be directed through a door or through holes in the furnace wall.—D.L.C.P.

Removal of sulphur and phosphorus in acid electric steelmaking V. J. Ivanov *Iron Coal Trades Rev.*, 1960, **181**, Aug., 411–412; from *Metallurg*, 1960, (3)) The practice followed at Luganksi for removal of sulphur and phosphorus in an acid-arc electric furnace to avoid operating one furnace of the electric melting shop or a basic-lined furnace in order to produce occasional casts of low-sulphur and phosphorus steels is briefly shown.—S.H.-S.

Improving the quality of chromium–aluminium steels of 35 KhYuA type G. A. Khasin and V. N. Davidyuk (*Stal'*, 1960, (9), 808) A note from Zlatoust. In the basic arc-furnace, instead of Fe–Mn, Mg iron was added to deoxidize and Si–Mn was added. After removal of slag the Al was put in. Various savings are noted.

Efficiency of the use of oxygen in arc furnaces V. A. Romenets, N. P. Bannyi, and V. A. Ageeva (*Stal'*, 1960, (9), 855–860) The special advantages of arc furnaces over converters and OH furnaces for oxygen steelmaking are discussed. Efficiencies are calculated and, in particular, metal losses, which rise as oxidation is carried nearer completion in the arc furnace.

Big electric arc furnaces replacing open hearth shop (*Steel*, 1960, **147**, Aug. 29, 156) The new Demag-type electric arc furnaces planned to replace the existing 21 OH furnaces of Steel, Peech & Tozer at Templeborough, Rotherham, are briefly described.—S.H.-S.

A stator with a bar winding for stirring the metal in an arc furnace D. F. Gladkii, A. Ya. Kovalenko, and N. V. Okorokov (*Stal'*, 1960, (10), 905–910) An Al bar winding of the form illustrated is superior to a copper coil winding when tested on the same furnace. The advantages of stirring are considered, and for slag removal it is shown that the rate of agitation should be increased.

Arc furnace transformers L. Smith (*Elect. Times*, 1960, **138**, Oct. 20, 606) Factors in the choice and maintenance of transformers are briefly considered.

The properties of the magnesite fettling mass for electric steel melting furnaces A. A. Pirogov and F. Z. Dolkart (*Ogneupory*, 1960, (3), 114–122) To obtain a carbon-free fettling mass, highly calcined MgO should be used which does not contain free lime in the sulphite waste liquor. The MgO mass with additions of sulphite liquor has high refractory properties and resists hydration during drying and firing the rammed hearths. During operation, because of the effect of the molten metal mass at high temp., a gradual sintering of the rammed mass in the hearth develops.

Dust formation in electric furnaces using oxygen M. N. Kaibicheva (*Stal'*, 1960, (9), 809–812) The amount, particle size, and composition of the dust formed in the electric furnace and its reactions with refractory linings were examined. Reactivity with silica is high and magnesite–chrome should be substituted. A process losing less metal as oxides by volatilization is required.

A practical method of deoxidizing steel with aluminium in the ladle V. A. Skachko and P. D. Sbezhnev (*Stal'*, 1960, (9), 789–793) Effects of Al addition are outlined and the conduct of the operation in two stages is discussed. Trials were made on 0·28–0·39%C steel in 3-t ladles and a process of adding FeSi before tapping and forcing in Al rods wrapped in sheet iron after tapping is favoured.

Deoxidation and alloying of 25G2S steel with ferro-manganese and ferro-silicon in 200-ton ladles V. G. Mal'kov, V. I. Prilepskii, and V. S. Dubrov (*Stal'*, 1960, (9), 803–806) Less Fe–Mn is used in the ladle than is required in the furnace and the heat time is reduced by 18–20 min. Distribution in the ladle is substantially uniform and properties, structure, and number of inclusions remain satisfactory.

The production of alloy steels S. K. Nanavati (*Trans. Indian Inst. Met.*, 1960, **13**, March, 3–12) The present production of alloy steels in India is very low. Suggestions are put forward for the extent to which production should be increased in the next five years.—A.D.H.

Proper design of large rail ingot moulds L. A. Bol'shakov, M. T. Bul'skii, E. K. Turchenkova, R. M. Egnus, F. F. Sviridenko, L. P. Tarasova, P. N. Slepkanev, and V. Z. Gavrikov (*Stal'*, 1960, (9), 793–797) High mould consumption was caused by the thick wall of closed bottom moulds and this has now been reduced and equalized. Studies of the moulds and trials of the newer designs are reported. Small additions of Cr and Ni to the iron are advantageous and also modification with Fe–Ti. Large savings are expected on the economy in metal alone.

Studies of ingot mould life by statistical methods J. Czarny and B. Pajak (*Prace Inst. Hutn.*, 1960, **12**, (3), 111–129) Preliminary studies of the effects of various factors on the life of moulds have shown the great influence of the manufacturing conditions, idle time, and

temp. before teeming. Further investigation indicated that life is most influenced by the following: (1) Idle intervals between teeming. (2) Intervals between the beginning of teeming and stripping. (3) The mould dressing. (4) The distribution of graphite in the structure of the cast iron. It was found that mould life could be increased substantially by keeping these factors within prescribed limits and that this could be done without too much expense and difficulty. By considering two factors only (1 and 2), mould consumption was decreased from 15 to 10 kg/t of steel.

Reducing the oxygen content of an over-refined steel melt by means of a lime slag K. Schneider (*Neue Hütte*, 1960, **5**, Aug., 441–446) The relationship of the O_2 content of the melt at the end of refining to slag composition, C, Mn, P content and temp. is represented, and it is shown that the O_2 content of a low C and Mn bath for transformer steel can be reduced by about 30% by removing the slag and building a new lime slag, under the conditions described. The influence of O_2 content on eddy-current losses in transformer steel is examined (33 refs).

Collapsible umbrella mould used to make hot tops Lukens Steel Co. (*Steel*, 1960, **147**, July 4, 76–78) A collapsible metal umbrella fitting tightly against the inner wall of the ingot mould until the hot top hardens, the so-called tiger-top, is described.—S.H.-S.

The development of the Valiak feeding head for use in the steel industry (*Mines Met.*, 1960, Sept., 481–482) This article describes a new type of ingot mould head first used in Sweden in 1953. This consists of rectangular bricks made of coke dust, sawdust, and an agglomerant and has been used very successfully in eliminating shrinkage of the ingot at the moment of solidification.

Ball-bearing steel heated with synthetic slag S. G. Voinov and A. G. Shalimov (*Stal'*, 1960, (10), 902–904) Treatment in the ladle with a $CaO–Al_2O_3$ slag reduces S, O, and non-metallic inclusions and increases electric furnace output.

Deoxidation and desulphurization of steel by aluminium V. A. Skachko (*Lit. Proizv.*, 1960, (7), 43–44) The experiments here reported made it possible to derive a mathematical relation for calculating the optimum amount of Al to be introduced into the steel by means of tubes: for carbon steels for rolling and forging $\%Al = 0{\cdot}005(\%C)$ and for carbon steels intended for shaped castings or for steels with controlled grain size, $\%Al = 0{\cdot}005(\%C) + 0{\cdot}0185$.

Effect of melting temperature and practice upon nonmetallic inclusions in bearing steel E. S. Kalinnikov and A. M. Samarin (*Proizvodstvo Stali, Collection of Papers xxxv*; I. N. Kidin (Ed.), 1956, 290–297) Melting and pouring conditions were investigated on a 1%C, 1·5%Cr ball-bearing steel, with the object of obtaining a steel as clean as possible. It is shown that the steel should be poured at the lowest temp. consistent with casting a sound ingot. Most of the non-metallic inclusions are formed during the steelmaking process.

Increasing yield by filling the feeder head region of ingots with electro-slag G. A. Khasin and V. N. Davidyuk (*Stal'*, 1960, (9), 807–808) A note from Zlatoust and the E. O. Paton Welding Institute. White refining slag and runner scrap from the same type of steel are used and kept molten with a 40 V–1500–1700 A current. Discard is reduced.

A new method of casting ingot moulds during the teeming of steel G. A. Khasin and V. N. Davidyuk (*Stal'*, 1960, (9), 807) A note from Zlatoust. Petroleum jelly, paraffin, or stearin is introduced into the hot mould and covered with a lid. A reducing atmosphere and a uniform covering of soot are formed. Surface quality of the ingots is improved.

Operational data and lining characteristics of large-capacity arc furnaces O. Porkert (*Stahl Eisen*, 1960, **80**, Nov. 24, 1770–1775) Constructional and operational data of 33 large-capacity arc furnaces from eight countries are listed and compared with particular reference to lining practice. The author regards the lining of the walls and the lids in many cases as still unsatisfactory and suggests modern methods of lining and lining application which might bring about an improvement.—T.G.

On the relation between characteristics of high-alumina furnace roof brick and arc melting condition S. Nishikiori, S. Nagata, S. Niwa, and Y. Konishi (*Denki-Seiko*, 1959, **30**, May, 256–270) [In Japanese].—K.E.J.

Mains network disturbances caused by arc furnaces F. Walter (**Elektrotech.*, 1948, **11**, Aug., 217–220) Causes of current and voltage fluctuations in arc circuits are analysed, and means for suppressing them in a high-tension circuit, and for smoothing the power transformation are discussed.

The direct use of Krupp–Renn iron for making steel in the arc furnace K. F. Lüdemann (*Neue Hütte*, 1960, **5**, Oct., 617–618) The Krupp–Renn iron produced in the German Democratic Republic has a total Fe content of 92% and contains 0·60%C, 0·45%Si, 1·20%P, and 1·85%S. The extremely high levels of P and S present great difficulties in refining, hitherto it could only be used in the blast furnace. But tests are being carried out with the arc furnace for using this iron directly for making steel. After melting-down, powdered lime, and other highly basic substances are blown into the melt using a carrier gas. By this method, even low S levels could be reduced considerably for instance from 0·90% to 0·045% by three treatments, with changing of slag.—T.G.

Basic electric furnace practice for low alloy steels U. K. Bhattacharya and B. K. Gupta (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 489–491) Notes on charging, refining, and finishing practice, with examples of the progress of two typical low-alloy heats.

Low-cost slag thinner reduces refractory-attack damage R. K. Buhr and W. A. Morgan (*Iron Age*, 1960, **185**, June 9, 110–112) The performance of a new slag-thinner called 'Sorelflux' is described. This material consists of cyclone tailings from ilmenite iron-ore deposits. It can replace fluorspar weight for weight and give similar results, but costs only one-third as much. Further savings result from reduced refractory attack. Operating results on electric furnaces making SAE 1010-semi-killed and 1075 grades are given.—DIL.C.F.

On the behaviour of hydrogen in molten steel. III. Investigation into the oxidizing period of the basic arc furnace process (*Denki-Seiko*, 1960, **31**, Jan., 14–22) [In Japanese].

Steel works moulds D. V. Paranjpe, S. Visvanathan, and V. G. Paranjpe (*Indian Construction News, Special No.*, 1958, **7**, Nov., *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, 5–8, Feb., 309–315) Method of manufacture, typical mould defects and their control, and factors influencing mould life are reviewed (11 refs).

On the reducing hot top and its shapes K. Sakai and T. Takahashi (*Denki-Seiki*, 1959, **30**, May, 239–247) [In Japanese].—K.E.J.

The top casting of steel J. Natkaniec and Z. Majewski (*Hutnik*, 1960, **27**, (5), 172–182) The authors deal exhaustively with the problems of top casting and arrive at the following conclusions: in view of the many advantages of top casting, such as better utilization of floor space and saving in refractory materials, this method should be more thoroughly investigated, and introduced into Poland. The first steps in this direction should be made in works casting great quantities of steel. Lower quality must be expected, but this can be counteracted with flame cleaning.

Industrial production of 18 HGT steel B. Rusu (*Met. si Constr. Masini*, 1960, **12**, (6), 491–494) It has been established experimentally that when the steel rises to half the ingot height without a crust and forms then a thin skin which can be eliminated in a reducing atmosphere (by additions of pitch, wood, or coke-oven gas) the steel gives the least rejects. The casting temp. should be so adjusted as to allow the formation of the normal skin on the meniscus with a pouring rate of 4 min 45 sec for a 3·3 t ingot (to the feeder head). Pouring at lower temp. should be avoided as crust formation cannot then be prevented.

Deoxidation and alloying of chromium-containing steel with silico-chromium in the ladle B. G. Petukhov and P. K. Morokov (*Metallurg.* 1960, (10), 12–14) Between May and Sept. 1959, 60 experimental heats were carried through at the Kuznetsk combine (Cr, Cr–Ni, and Cr–Si–Mn steels). Details are given of the heats and also of the mechanical properties of the steels produced with Si–Cr introduced into the ladle.

Production, properties and use of semi-killed steel K. Fellcht and H. J. Eckstein (*Neue Hütte*, 1960, **5**, Oct., 590–596) After reviewing the literature on semi-killed steel the authors describe their studies on the production of this type of steel. They added Si and Al in the ladle to a steel of the type 0·10–0·20%C, 0·08%Si, 0·45%Mn, 0·035%P, and 0·045%S. Its mechanical properties were good, it showed better ageing behaviour than a steel killed with Si.

The design of continuous casting plants for India N. N. Dastur and R. D. Laikaka (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 369–381) Various aspects of the continuous casting process are considered, features of existing plants are described, and possible advantages for Indian conditions are discussed. These include: suitability for small steelmaking units; ease of manufacture, without the need for blooming mill equipment which cannot at present be produced in India; utilization of existing re-rolling capacity, and the lower capital investment required (28 refs).

Study on the continuous casting of steel. II. on secondary cooling in continuous casting Y. Aketa and K. Ushijima (*Tetsu to Hagane*, 1960, **46**, July, 753–757) Work on square billets shows that, to prevent deformation and cracks, roller aprons must be set up and the spray cooling kept even. Internal cracks can be prevented by a given intensity of spray for each grade of steel. Too high a casting temp. produces internal cracks (16 refs).—K.E.J.

The use of radioactive isotopes in the inspection of the technology of the continuous casting process C. Varga and J. Fodor (*A/CONF.15/P/2240*, pp.8; *Nucl. Sci. Abs.*, 1959, **13**, April 30, 913–914) The depth and profile curve of the liquid zone were determined by using radio-isotopes; the techniques used are described.

Solidification mechanism of molten steel. II A. Yamamoto (*Denki-Seiko*, 1959, **30**, May, 271–278) [In Japanese] A review with 39 references.—K.E.J.

Effect of gravity on the macro-segregation of larger steel ingots S. Onodera and Y. Arakida (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 358–368) Solidification curves along the core axis of 3–140 t ingots were drawn on the basis of results of bar tests, and metal adhering to the bars was analysed. The results are discussed in the light of segregation theory. Further experiment are described in which the behaviour of segregates in sand cast ingots solidified with their axes inclined is investigated, and the effect of gravity on V and inverse-V segregation examined. The results are assessed.

PRODUCTION OF FERRO-ALLOYS

Ferrochromium and metallothermal alloys with low carbon content G. von Hofsten (*Tek. Tids.*, 1960, **90**, April 8, 389–393) The decarburization of high-carbon ferrochromium, and the metallothermal production of ferro-molybdenum and ferrovanadium are discussed.

Water conditioning in the production of ferroalloys J. R. Lee and V. H. Street (*Blast Furn. Steel Plant*, 1960, **48**, May, 470–471) Plant and procedures in use at the Vancoram, Ohio, plant of Vanadium Corp. of America are described briefly.

FOUNDRY PRACTICE

The foundry industry in the German Democratic Republic F. Naumann (*Koh. Lapok,-Öntöde*, 1960, **11**, Jan., 1–10) The development and present state of the foundry industry in the German Democratic Republic are described in the paper.—P.K.

Scope for development of foundry industry in India R. M. Krishnan, T. Banerjee, and P. K. Gupta (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, 5–8, Feb., 345–350) Present distribution of Indian foundry capacity, types, and numbers of castings produced, availability of raw

materials, and developments envisaged in the Five Year Plans are discussed.

The development of foundry technique in Hungary J. Payer (*Koh. Lapok-Öntöde*, 1960, **11**, May, 97–99) The guiding principles of the development of foundry technique in the period of the second five-year plan of Hungary (1960–5) are briefly discussed.—P.K.

Some aspects of Indian foundry raw materials S. N. R. Rao (*Trans. Indian Inst. Met.*, 1960, **13**, March, 77–82) The availability and the chemical and physical characteristics of Indian sands, bentonites and clays, fuels and metals, ferro-alloys, and scrap are reviewed.

Thermal properties of moulding materials A. Ramachandran (*Trans. Indian Inst. Met.*, 1960, **13**, March, 39–47; discussion 47–51) The mechanism of heat transfer in sand and metal moulds is discussed and data on the conductivity of moulds are reviewed.—A.D.H.

The design of castings for production J. B. McIntyre (*BCIRA J. Res. Dev.*, 1960, **8**, May, 393–397) Principles of good design should be applied to all castings to obtain quality and economy in production. A suitable approach to castings design is outlined. Consultation between designer and foundryman is urged and many of the main difficulties are discussed.

The design of iron and steel castings G. Jándy (*Koh. Lapok-Öntöde*, 1960, **11**, June, 121–125; July, 160–167) The main principles of the selection of an appropriate alloy and of the design of up-to-date castings are discussed in the paper.—P.K.

The foundry in the car industry J. Pomey (*Fond. Belge.*, 1960, **30**, July–Aug., 202–205; from *Met. Ital.*, 1950, Feb.) This article describes the various types of casting needed in the car industry: grey iron, malleable, pearlitic, and diffused annealed graphite iron.

Production of foundry silicon M. Cavigli (*Met. Ital.*, 1960, **42**, Aug., 577–583) This article examines the values of the thermodynamic functions in relation to the reduction of silica and oxide impurities by carbon. The formation of SiO, it is emphasized, is the cause of energy and material losses. The author then describes the electrothermic process in relation to the submerged arc electric furnace.

The effect of flushing hot iron with methane on its castability L. Sofroni, C. Cosneanu, and E. Nicoloiu (*Rev. Roumaine Met.*, 1960, **5**, (1), 47–57) [In French] Part of the CH_4 is dissociated, depositing carbon in the form of soot and liberating nascent H. H_2 is included in the CH_4 bubbles which rise to the surface, flushing the hot metal, while the soot forms spheroidal graphitization centres. This improves the mechanical properties of the metal, reduces the tendency to crack formation and increases fluidity.

What kind of machines and equipment do our foundries require? J. Širokich (*Slévárenství*, 1960, **8**, (6), 189–195) Problems connected with the intensive mechanization, automation, and modernization in progress in Czechoslovak foundries are reviewed.—P.F.

Our foundry at Werdohl A.G. Hoesch (*Werk Wir*, 1960, Sept., 255–259) A brief description with illustrations.

New line doubles foundry yield in half floor space G. Charles and A. J. Kipp (*Iron Age*, 1960, **185**, April 28, 101–103) A mechanized foundry line based on an L-shaped loop conveyor which replaced a manually operated plant, gave double the capacity with fewer operators.—D.L.C.F.

Modernization of the TOS Foundry in Čelákovice A. Hruška (*Slévárenství*, 1960, **8**, (8), 266–270) Expansion and modernization of the foundry, which produces castings for metal working machines weighing up to 6 t, is described.—P.F.

How the new grey cast-iron foundry in Čelákovice will be equipped J. Matějka (*Slévárenství*, 1960, **8**, (8), 270–277) Organization and equipment for a projected large foundry specializing in large grey cast-iron castings for metal working machines is discussed.—P.F.

Foundry plant. X G. Somigli (*Fond. Ital.*, 1959, **8**, Oct., pp.359–364) The author describes with the aid of examples the criteria governing the location, construction, internal lighting, ventilation, heating, crane installation, and type of floor in a new mechanized foundry. He describes the deployment of auxiliary services and then the movement of materials, giving a flow plan.

Practical notes on the technical and administrative organization of an average size non-mass production foundry O. Ciangaretti (*Fonderia*, 1960, **9**, July, 301–307) A short account is given of ways of reducing costs and increasing productivity by time study, production sheets, piecework, and other incentives, statistical study, and improvement of methods.

Standardization in the foundry (*Trans. Indian Inst. Met.*, 1960, **13**, March, 83–86) The present position regarding the establishment of Indian foundry specifications is presented.

Defending the cupola Y. Lamoureux (*Fond. Belge*, 1960, **30**, July–Aug., 206) The writer replies to criticisms made of the cupola furnace, claiming that cupola production is from 90–130 kg/h and that the process is more economical. He states that a temp. of 1450–1490° can be obtained from beginning of melting and maintained for hours using a cold blast cupola with superheated hearth. He claims also that if the furnace is operated efficiently the proportion of rejects is no greater than with any other furnace. With the cupola, constant quality iron can be obtained.

Fire lighter extraordinary (*Torch*, 1959, Summer, 18–19) The use of an oxygen lance and an oxy-propane blowpipe in lighting foundry furnaces is described. The method eliminates the smoke produced by an ordinary wood and coal fire and is consistently efficient and economic.

The theory and practice of the metallurgical blast cupola. II G. Somigli (*Fond. Ital.*, 1960, **9**, July–Aug., 312–320) This article compares the metallurgical blast cupola furnace with all other types of cupola furnace outlining its development and geographical distribution. A full description of its design and operation is given.

The economics of controlling hot and cold blast cupola emissions F. M. Shaw (*BCIRA J. Res. Dev.*, 1960, **8**, May, 343–350) The present legal position of both hot and cold blast cupolas with regard to the Clean Air Act is reviewed. Costs for the types of arrester favoured for use on cold blast cupolas are given. A method of treating the water in wet arresters with soda ash is outlined; such treatment is essential to keep maintenance costs at a reasonable level. The approximate costs of implementing the provisional agreement made with the Chief Alkali Inspector regarding hot blast cupolas have been tabulated.

Operation of the cupola furnace and efficiency of smelting Lee Hsu-lin (*Proceedings of Metallurgy*, 1958, (47), 29–31; from *Sci. Abs. China, Techn. Sci.*, 1959, (1), 50) Measures adopted at Hsin Sing Steel Works for increasing the life of the cupola and improving smelting efficiency are reported in detail. Improved design and construction, increased blower capacity, and hot blast are made use of, and measures to conserve the blast are recommended.

The use of calcium carbide in the cupola E. Černáček and J. Neumann (*Hutník*, 1960, **10**, (8), 308–310) Experiments with additions of CaC_2 to the cupola showed that the temp. of the cast-iron in the runner was increased by about 40°C. The amount of steel scrap used could be increased, and the sulphur content of the iron was reduced by about 20%. The output of the cupola was also increased. The composition of the charge with which CaC_2 additions give most economical results are indicated. Further work must proceed before a full evaluation becomes possible.—P.F.

Slags in the cupola process J. Gibinski and S. Komorowski (*Prz. Odlewn.*, 1960, **10**, (7–8), 202–211) The article gives the results of investigations into the action of the slag on the iron in the basic and acid cupola processes as well as the theoretical reasons behind the reactions. The mechanisms of sulphurization and desulphurization are described as well as the effect of temp. and chemical composition in this process. The results concerned with the effect of the basicity of the slag on the carburation of the iron in the cupola are discussed. In addition a method employed to determine quickly the quality of the slag is described.

Air and vacuum steel melting induction furnaces, their design and operation A. Belly (*Rev. Mét.*, 1960, **57**, Aug., 679–693) Various designs of low- and medium-frequency induction furnace and their characteristics are described in detail, and a shorter section is devoted to a similar treatment of vacuum induction furnaces.

Strong wooden frame used for erecting the two cupolas at the IMB Timisoara G. Munteanu (*Met. i Constr. Masinî*, 1960, **12**, (6), 541–543) The wooden frame is described. It supports a lifting tackle on a high platform 5 m from the floor of the shop with sufficient free space to manipulate a section of the cupola 1500 mm dia. and weighing 1·5 t.

The combustion zone in large cupola furnaces V. P. Chernobrovkin and A. A. Anan'in (*Lit. Proizv.*, 1960, (10), 8–9) The combustion zone in cupola furnaces is characterized by the chemical composition of the gas phase, and also by the temp. and the volume in which combustion takes place. The main components of the gas phase are CO_2, CO, O_2, and N_2. Changes in the ratios of these components are studied so as to understand more fully the combustion process.

Increasing productivity by use of a refractory gun E. Fröbel (*Giessereitechn.*, 1960, **6**, Oct., 309–310) Although a new refractory gun for repairing the lining of cupolas brings about a financial saving of 30% of the usual repair costs, many works do not use it, on the contrary some who had it sold it again. This practice must be stopped and even in cupola fettling every effort should be made to reach the world standard, i.e. the gun should be used by all foundries. Operation of the gun in question is briefly described.—T.G.

Quality of coke for cupola use N. N. Das Gupta and A. Lahiri (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 225–229) Composition and physical properties of foundry coke and specifications for coke produced in various countries are reviewed, and shortcomings of much of the foundry coke produced in India are discussed and remedies suggested (11 refs).

Relationships between the properties of coke and its behaviour in the cupolas W. Patterson, K. Löhberg, and A. Dahlmann (*Giessereí Techn.-Wiss., Beih.*, 1960, July, 1581–1605) Comparison of the results of laboratory tests on seven types of coke with their behaviour in the cupola showed a close relationship between iron temp. and the specific surface area, such that iron temp. rises with area. The results reported in the literature are surveyed critically (94 refs).

Charging of cupolas with central charging installation by an inclined hoist R. Kind (*Giessereitechn.*, 1960, **6**, Oct., 308) A new design of an inclined hoist for cupolas with central charging devices is described and the charging operation when using such a hoist explained.—T.G.

The effect of steel scrap in the mixture for melting iron in the cupola H. Siepmann, H. Pacyna, and H. W. Hauptvogel (*Giesserei*, 1960, **47**, Nov. 3, 608–614) The proportion of steel scrap to pig iron in the mixture for melting in the cupola is discussed from the point of view of economic conditions and technical effects. Statistical evaluation shows that the composition of the mixture is decided mainly by current prices of the raw materials. Critical review of published information shows that claims for an advantage in using high proportions of steel scrap cannot be substantiated, particularly in the hot-blast cupola with basic lining. The effect of composition of the mixture on the quality of cast irons still involves a number of uncertainties (37 refs).—T.G.

Special methods in cupola practice. III W. Friedel (*Giessereitechn.*, 1960, **6**, Oct., 295–296) In this instalment the author reviews hot-blast cupola practice with particular emphasis on the operation of the hot-blast stove and the difficulties experienced in its operation (21 refs).—T.G.

On the question of burning solid fuel in cupola furnaces A. B. Genin (*Lit. Proizv.*, 1960, (10), 7–8) The thermal and metallurgical processes are discussed. Intensifying the process

by increasing the gas flow rate, heating or enriching the blast with O_2 and the porosity and reactive capacity of the fuel are almost without effect on the CO/CO_2 ratio and, in addition, a high CO content in the waste gas indicates a high temp. in the blank charge. There is thus a basic contradiction between increased output and temp. of metal produced, and a reduction in the coefficient of complete combustion and thermal efficiency.

Notes on the operation of a cupola with constant profile S. Komorowski (*Prz. Odlew.*, 1960, **10**, (10), 277–284) The author states that one of the conditions for satisfactory operation is the correct construction of the nozzle assembly and of the cooled parts of the cupola. Large velocities should be maintained in the air at the nozzle outlet. These factors have a profound effect on the location and shape of the melting zone. It was observed that small variations of blast caused considerable deformation of the melting zone.

Experimental melting with calcium carbide additions in the cupola W. Hass (*Giessereitechn.*, 1960, **6**, Oct., 239–295) The author reports details of some trials of melting iron in the cupola with CaC_2 additions, but he emphasizes that the only conclusion that could be drawn from these experiments was that the applied melting practice was not correct nor was the quality of the carbide at all suitable.

Methods of overcoming the wall effect in cupolas G. L. Shires (*Castings*, 1960, **6**, March, 33–37) A paper presented at a Symposium of the Coal Research Section, CSIRO, 1960, March 2. A model cupola of 12 in internal dia. and with adjustable tuyeres is used to explore the effect of distribution of coke on the uniformity of the air blast. 40% of the air passes up an annulus near to the wall. Partial success was obtained by charging fine coke adjacent to the wall so that more blast goes to the centre.

The effect of heating the blast on the combustion process in a cupola furnace M. K. Sin (*Lit. Proizv.*, 1960, (10), 4–6) The main effects of heating the blast on the combustion process in a cupola furnace are to extend the high-temp. area, increase its temp., increase the CO/CO_2 ratio in the gases, and to reduce the oxidizing and extend the reducing zones.

Electric melting furnaces L. G. N. Edwards (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 193–199) The use of arc, graphite rod, and HF induction furnaces in the steel foundry is reviewed, and iron foundry applications are outlined.

Electric arc furnaces Bradley & Foster Ltd (*Bradley's Mag.*, 1960, Spring, 6–7) Construction, charging, melting, and foundry use are very briefly outlined.

The induction furnace and cast iron C. Tama (*Ing. e Indust.*, 1960, July, 124–129) The advantages of induction furnaces for making cast irons are described.—P.S.

The induction crucible melting furnace in the grey iron foundry G. Hoffmann (*Giessereitechn.*, 1960, **6**, June, 175–180) The characteristics of mains and medium frequency induction crucible furnaces, and the techniques of grey iron manufacture in them are discussed.

Modern induction melting practice in the foundry B. V. Prabhu (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 201–210) In the first part of the article, the main features of the medium-frequency induction furnace and its use in the manufacture of plain C, stainless, and high-speed steel are described. The low-frequency induction furnace is described in the second part, and examples are given of its application to the production of whiteheart malleable cast iron (10 refs).

Melting practice in induction furnaces H. Godfroid (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 211–217) The main features of the crucible type coreless and low-frequency core type induction furnaces are described, and their advantages and drawbacks discussed. Some results obtained in high and medium frequency furnaces are outlined.

Steel-melting test in crucibles made of pit refractory (*Denki-Seiko*, 1960, **31**, Jan., 35–39) [In Japanese].—K.E.J.

A coated cast iron crucible for use with eutectic Al–Si alloy in the temperature range 595–650°C F. L. Yaggee (*ANL–5673*, 1960, Feb. 4, pp.37; from *Nucl. Sci. Abs.*, 1960, **14**, Sept. 30, 2321) Enamelled pots were found to resist oxidizing atmospheres for 3 months at 725°C. A crucible was tested successfully for 144 days at 595–650° with 450 lb Al–Si alloy. The coating is very effective on low-expansion alloys low in Cr and Ni.

The wear of Hadfield steel used for castings A. Lorenc and K. Stránsky (*Slévárenství*, 1960, **8**, (8), 277–281) Factors in production and use of 12% austenitic Mn steels are discussed. Fracture surface examination provides a suitable means for determining austenitic grain size.

Metal penetration in Hadfield steel castings L. Rotter and K. Stránsky (*Slévárenství*, 1960, **8**, (6), 195–199) Scabs and other surface flaws observed in castings of austenitic 12%Mn steels were studied. It is shown that with acid moulding mixtures their incidence is conditioned largely by high pouring temp., hot spots in the mould, and by the thickness, cohesion, and other properties of the mould dressing at high temp.—P.F.

Testing of moulding sands P. Németh (*Koh. Lapok-Öntöde*, 1960, **11**, April, 86–94) The author compares critically the Hungarian (HNOSz), German (DIN), and American (AFS) standards for the testing of moulding sands.—P.K.

Hot testing of moulding sands T. Budinszky (*Koh. Lapok-Öntöde*, 1960, **11**, April, 73–85) The method described is suitable for testing the properties of moulding sands at casting temp., and for determining the optimum amount of Na_2CO_3 and optimum used-sand ratio in the mixture. The Na_2CO_3 is needed for activating the bentonite.—P.K.

Group method of pattern moulding R. D. Babitskii (*Lit. Proizv.*, 1960, (7), 37–38) At a Moscow lathe manufacturing plant, moulds for a few components of one type or even for individual castings are moulded on machine type 271 which has been adapted to operate by groups. For the purpose the bottom plate has, according to the dimensions of the castings, one to four mould flasks separated by an Al cross. Bottom plates with one to three flasks can serve for components of up to 25 kg in weight.

Pattern materials: Their characteristics and criteria of choice S. Ramamurthy (*Trans. India Inst. Met.*, 1960, **13**, March, 53–74; discussion 74–76) The choice of pattern materials for the body, surface and joints are discussed with special reference to phenolic and epoxy resins. The influence of the surface of the pattern on the mobility of sand in adjacent layers by a V-notch test and the effect of surface mobility on surface finish was investigated.—A.D.H.

Easily detachable two-sided bottom plate P. I. Mironov (*Lit. Proizv.*, 1960, (7), 38) With moulding machines types 271 and 261, a provision is explained to change the bottom plate. For this purpose a special frame has been designed at the Leningrad Mechanical Repair Works, which is mounted on a table of the machine by means of bolts. Drawings are given.

Mechanization of a production line for mould mixture slinging A. S. Shuper and L. Ya. Melekhin (*Lit. Proizv.*, 1960, (7), 14–16) A production line is described consisting of, in the main, a turntable with hydraulic drive for half moulds, a mechanized roller-conveyor, and a drying unit for the half mould surfaces. Its chief technical characteristics are: length 2000–3000 mm; width 100–2500 mm; height 300–900 mm. The maximum weight of the half mould is 2000 kg. The distance for extraction is 630 mm for a box 930 mm high. Capacity, four half-moulds per h.

The coefficient of variation as a measure of the degree of mixing of moulding sands R. Chudzikiewicz (*Prz. Odlewn.*, 1960, **10**, (7–8), 212–218) The quality of mixing of loose sands is measured by the standard deviation of the content of a component determined in samples of constant size. The methods used at present are examined and their faults pointed out. As a more correct and convenient measure of the degree of mixing it is suggested that the relationship between the standard deviation of the values for a component, and the average content of this component be used.

pH. New control method for foundry sands J. Castells (*Fond. Belge*, 1960, **30**, July–Aug., 189–194) This paper deals with the determination of the cause of a surface defect which appears on grey iron and steel castings when moulding sand is used after a long shutdown. The scab defect appears whether natural or synthetic sands are used. A method of control consisted of measuring the acidity or basicity of the sand mixture and the author proposes the determination of pH value as a new control factor. Raising the pH value by adding alkaline products to the return sand gives entirely satisfactory results in eliminating the defect. (Sept., 234–239) A scab defect on grey iron and steel castings was remedied by controlling the pH of the sand mixture. Determination of pH of sands is proposed as a new control factor (17 refs).—R.P.

Ternary constitutional diagrams of moulding sands F. Varga and E. Farago (*Koh. Lapok-Öntöde*, 1960, **11**, May, 106–111) The authors describe the construction and use of ternary constitutional diagrams of moulding sands for the determination of the optimum degree of ramming, i.e. the necessary number of strokes.

Sand moulding with type 115 sand mixing machines N. V. Shtengel'meier (*Lit. Proizv.*, 1960, (7), 36) Previously, sand moulding was carried out on the drying and sand moulding machine type 3M–2 on which the operation lasted one hour. The new machine termed a 'complete moulding machine' type 115 with a 300 kg sand charge reduces the operation to 15 min and has in addition other advantages. Certain improvements in its construction are suggested.

The evaluation of bentonite in the steel foundry V. E. Zang (*Trans. Indian Inst. Met.*, 1960, **13**, March, 19–34; discussion 34–37) Attempts to assess the suitability of bentonite on the basis of co-operative tests by the Steel Founders Society of America include tests for moisture, pH, lime content, and the plastic viscosity of a slurry. Testing methods are described, but the present specification does not completely define the suitability of the bentonite.—A.D.H.

Loam moulding a casting for the chemical industry M. W. Gartland (*Brit. Found.*, 1960, **53**, May, 242–244) The casting of a hooded plate by strickle moulding is described.

Mechanised production of cores F. Varga and E. Farago (*Koh. Lapok-Öntöde*, 1960, **11**, June, 126–132) After giving a short historical survey, the authors review the various types of core producing (blowing, slinging, etc.) machines.

The hardening of drying oils in core sand C. van der Weteringh (*Metalen*, 1960, **15**, Aug. 15, 256–264) This opening instalment of the paper discusses the mechanism of the hardening of drying oils and particularly their behaviour in core sand. On the strength of a preliminary investigation, several methods of accelerating the hardening of such sands are described. To conclude, attention is directed to the phenomena that are encountered when core sand is heated.—F.R.H.

The use of green cores I. Szilágyi (*Koh. Lapok-Öntöde*, 1960, **11**, July, 157–159) Two examples of the use of green cores: (1) for sewing-machine frame wheels, (2) for fittings of malleable iron, are given in the paper.—P.K.

Preparation of hollow investment moulds by means of compressed air or liquid P. V. Sorokin and Ya. I. Nalivaiko (*Lit. Proizv.*, 1960, (7), 41) The walls of investment moulds of larger sizes are under a temp. gradient across their thickness when emptying the liquid cores and this causes distortion. It can be prevented in the new models by introducing air or liquid under pressure and examples are cited of moulds for gears 230 mm in dia. and 100 mm high, which are giving satisfaction.

The behaviour of moulding materials subjected to rapid heating in regard to scab formation H. G. Levelink (*Metalen*, 1960, **15**, July 30, 238–243) As a result of the investigation it may be concluded that the tendency to fracture of the skin formed on clay and oil sands when

rapidly heated with consequent scab formation can be reduced by increasing the original moisture content of the sand, by the use of Na-bentonite instead of Ca-bentonite, by the introduction of a fine aggregate such as silica flour or even by the inclusion of granulated pitch.—F.R.H.

Core assemblies for tractor crank case castings S. Šimoník (*Slévárenství*, 1960, **8**, (6), 199–201) A simple method for the introduction of the cores, utilizing a mechanical arm, was developed and tested. Data necessary as basis for the introduction of the method on a works scale were obtained.—P.F.

Ductile iron tyre moulds cast by complex process R. H. Herrmann (*Foundry*, 1960, **88**, Aug., 60–65) Four different types of ductile iron moulds used to make tyres, in which plaster, elastic vinyl polymer gel, resin-bonded sand, and green sand play an important part, with their respective uses and applications, are described and illustrated, with stages of the operations.—S.H.-S.

Manufacture of large castings by the CO_2 process O. Gerstmann (*Giessereitechn.*, 1960, **6**, June, 181–183) Examples are given of the manufacture of heavy iron castings (castings for a hydraulic press, slag ladle, and casting car) in USSR and Czechoslovakia.

Present-day CO_2 practice in South African foundries J. Steele (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 171–176) Types of sand used and various aspects of the technique used in S. African foundries are described.

Foundry experiences with CO_2 process C. A. Phalnikar (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 169–170) A comparison between linseed oil and CO_2 core practice.

Some observations on the recent developments in the CO_2 process B. V. Somayajulu, P. K. Gupte, and R. M. Krishnan (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 177–182) Trials carried out on the hardening characteristics of Rajmahal sand (which is widely used in West Bengal and Bihar) bonded with Na silicate are reported, including experiments with the use of N_2, compressed air and NH_3 instead of CO_2 for hardening.

Tiny precision castings allow totally new design freedom J. H. Cadieux (*Iron Age*, 1960, **186**, Aug. 18, 110–112) A new precision forming process—the Minicast—is presented, adapted to turning out complex precision parts for use in electronic equipment, machinery, firearms, etc. Two basic restrictions are laid down. First, the part must be less than one cubic inch in size. Second, it must be made in quantities exceeding 25 000 pieces. Examples and working tolerances are shown.

Production of the British Motor Corporation 'Series D' cylinder head casting L. W. Bolton (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 43–51) A description of the various stages of the production and inspection of a 102-lb cast iron cylinder head used in a six-cylinder motor car engine.

Investigations into the possibilities of the production of pistons for diesels in Poland Z Falecki (*Prz. Odlew.*, 1960, **10**, (9), 257–263) The chemical composition and the properties of the alloy intended for the manufacture of pistons are discussed. The results obtained during the casting of the pistons into sand and metal moulds are summarized. Technological parameters of casting these pistons into metal moulds and the influence of heat treatment on the properties of the cast pistons are given.

The casting of large crankshafts for Diesel engines M. G. Kvasman, A. A. Tunik, and B. E. Begun (*Lit. Proizv.*, 1960, (10), 13–15) The type D100 Diesel engine has two crankshafts (1315 and 1395 kg), and as a result of the work described it has been found possible to go over to the series production of these crankshafts from high-strength cast iron, at the same time maintaining all requirements as to their quality.

The technological process of casting crankshafts for the type DV-30 engine at the Vladimir tractor plant N. V. Gel'perin, V. V. Zvolinskaya, V. S. Parfenov, and A. D. Sherman (*Lit. Proizv.*, 1960, (10), 16–17) The technological process of casting crankshafts is described. This replaces the former forging process in the case of type DV-30 engines. Tests carried out so far indicate that mechanical and other properties are satisfactory and that the new method is more economical.

Metallurgical aspects and quality production of machine tool castings B. B. Mahabale (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 155–160) Alloy additions, design, and material control are discussed.

New technology for the production of semi-hardened rolls B. Raczynski (*Prz. Odlew.*, 1960, **10**, (9), 269–270) The rolls produced were of uniform hardness around the periphery (Brinell 240–350 kg/mm^2) and fall in hardness with depth was reduced. In the article details of production and chemical composition are given.

Manufacture of large size castings S. G. Athanikar (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 93–99) Several examples are given of the manufacture of large green and dry sand castings at the Kulti works of the Indian Iron and Steel Co. Ltd.

Modern techniques for the production of heavy steel castings C. J. Dadswell (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 101–110) A review of the main factors in the production of steel castings of 20–200 long t or more, with a comparison of moulding materials used in Europe and USA.

Centrifugally cast tubing gets boost in strength American Cast Iron Pipe Co. (*Steel*, 1960, **147**, Aug. 1, 82–84) A new process producing centrifugally cast tubing from ceramic moulds, which allow increased spinning speeds with denser and sounder castings of assured concentricity is described. **Casting centrifugally in ceramic moulds** J. C. Miske (*Foundry*, 1960, **88**, Aug., 52–56).

Mechanisation of permanent mould casting E. Brunhuber (*Giesserei*, 1960, **47**, Nov. 3, 634–639) The foundations of permanent mould casting are explained, the importance of the mechanical closing and opening of the mould is discussed and the principles of a number of casting machines (for non-ferrous metal) are described and their vital parts illustrated.

Some problems in shell moulding: the possibilities of shell cores A. Woods (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 183–190) Practical problems in the design of pattern plates, and factors contributing to the cracking of shell moulds are examined. Possible applications of shell cores are outlined.

Foundry shifts to shell moulds for large steel castings R. L. Jones and J. A. Rassenfoss (*Iron Age*, 1960, **186**, Aug. 4, 112–113) A switch from green-sand moulding to shell-moulding of steel castings weighing over 200 lb on a production basis is described.—S.H.-S.

Ceramic shell process to expand investment castings market R. H. Herrmann (*Foundry*, 1960, **88**, Aug., 158, 161–162) A recently developed ceramic shell investment process at Arwood Corp., New York, is briefly described.

Investment casting and some of its associated problems D. F. B. Tedds (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 231–239) The technique of the lost wax process is outlined, and a description is given of pattern materials, production and assembly, primary coating, mould drying and firing, melting, casting, fettling, and inspection.

The effect of air and moisture in the mould on iron castings L. Hajdu (*Koh. Lapok-Öntöde*, 1960, **11**, March, 65–70) The author describes methods of measuring the amount and of determining the effect of gases and steam, evolved from the moulds, on the iron castings.—F.K.

Solidification of castings. Part 2 W. F. Chubb (*Castings*, 1960, **6**, March, 17–30) A review of the literature from 1930 to 1945 covers a useful survey of foundry practice, to make best use of solidification phenomena, gating, feeding, segregation, chills and thermal properties of mould materials. Interests are mostly non-ferrous but there is a reference to thin steel castings (25 refs).—J.W.J.

Solidification of metal in iron moulds J. D. Keller and N. R. Arant (*Foundry*, 1960, **88**, Aug., 184) A curve relating the depth of solidification in white iron to measured temp. of specified depth in the chill mould is presented.—S.H.-S.

The 'growth' of cast iron—causes, and a recommended countermeasure H. Reininger (*Werks. Korros.*, 1960, **11**, Nov., 680–690) The causes of growth in cast iron are examined with reference to the literature, and factors tending to inhibit or promote growth are reviewed. Carbide breakdown is an important contributory factor, and a recommended procedure for eliminating this influence is to use iron which has been given a ferritic structure by annealing (84 refs).

Foundry defects and their causes during the casting of shell-moulded small, motor-cycle cylinders P. Januszewicz and T. Piwoński (*Prz. Odlew.*, 1960, **10**, (9), 249–256) An attempt is made to classify foundry defects produced during the casting of shell-moulded, iron motor-cycle cylinders of small size. Different kinds of defects, their causes and proposed remedies are summarized in tabular form.

Defective appearances on shell mould castings of low-carbon steel. Part 2 (*Giessereitechn.*, 1960, **6**, (6), 169–174) Methods are described for eliminating the porosity described in the first part; details of the experiment and conclusions drawn are given.

Quality control in the steel foundry U. K. Bhattacharya and B. K. Gupta (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 279–283) Properties of an acceptable casting are enumerated, and the influence of S, P, and dissolved gases on physical properties and soundness is discussed. The main features of the basic electric arc process and the necessary controls for the production of quality steel are described.

Casting quality control with dilatometer H. W. Dietert (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 272–278) A description of the restrained load test and the 1 psi test and illustrations of their use as elevated temp. tests to show whether a mould made from a given sand will yield castings free from defects such as scabs, buckles, or rat tails.

An evaluation of the efficiency of vibration during the separation of pattern from mould in moulding machines J. Lempicki (*Prz. Odlew.*, 1960, **10**, (10), 292–294) The author points out that vibration reduces pattern moulding sand friction in a very satisfactory way provided that operating conditions are correctly adjusted. The operational efficiency can be adjusted by observing and changing the air pressure in the lifting mechanism. Some results from Polish machines are quoted.

The complex mechanization and automation of the dressing of castings I. I. Sankov, A. I. Zibenberg, and V. S. Zhukov (*Lit. Proizv.*, 1960, (10), 23–26) The semi-automatic equipment used at the Gor'kiy works since 1948 is described in some detail. Five diagrams and two photographs are shown. Number of operations and time taken for the operations themselves, for transport, and for turning the castings are presented.

Regenerator installation for the hydraulic cleaning of castings M. G. Borovik and L. S. Solomon (*Lit. Proizv.*, 1960, (10), 17–21) The location of the hydraulic chamber in the foundry and of the regenerator department are discussed. It is pointed out that only a few works have basins for removing sludge from the hydraulic chamber and that it is usually impossible to remove it without separating the

liquid and solid phases. Actual installations are described.

Hydraulic and hydraulic-sand cleaning of castings L. P. Solov'ev (*Lit. Proizv.*, 1960, (10), 22–23) Various installations are compared. Factors which are taken into account include water pressure, the power of the pump, rate of water flow, output, water, and electric power consumption, and net cost.

Sulphur in the surface layers of steel castings M. I. Balashov (*Lit. Proizv.*, 1960, (10), 36–38) The author states that hot tears are often associated with sulphur content. An explanation is given for the presence of tears not only in the surface corresponding to the sulphur-enriched layer but also deep in the casting and frequently right through it.

Foundry ventilation K. Nilsson and Y. Bovin (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 375–385) General principles and methods are outlined, and examples are described of the ventilation of the moulding shop and other foundry localities. Capital and operating costs are considered.

The problem of estimating the net cost of castings I. S. Kagan and S. Ya. Gershtenkern (*Lit. Proizv.*, 1960, (10), 10–13) Several factors are considered including the choice of a unit for estimating the net weight of the product, the method of showing costs incurred on unfinished production, and the calculation of production costs and of the finished product in the steelmaking departments, including questions of theoretical and actual weights.

VACUUM METALLURGY

Low pressure metallurgy: vacuum as an inert atmosphere A. S. Darling (*Metallurgia*, 1960, **62**, Oct., 139–142) This is the second article in the series 'low pressure metallurgy' (*cf. ibid.*, 1959, Oct., Nov., and Dec.), and aspects considered include gas-tightness of a vacuum system, contamination during vacuum, melting of Fe, Ni, and U, and oxidation processes in the solid state.

The use of vacuum in metallurgy A. M. Samarin (Editor) (*Trans. of Primeneniye Vakuuma v Metallurgii*, 1958, pp.244; *F–TS–9571/v* [*NP*–tr–337]; from *US Techn. Trans.*, 1960, **4**, July 27, 114) No abstract.

A prepared discussion on 'consumable electrode melting of reactive metals' a paper by S. J. Noesen E. W. Johnson (*J. Met.*, 1960, **12**, Nov., 850–852) The paper by Noesen (*ibid.*, 1960, **12**, Nov., 842–849) dealt with the melting of some refractory non-ferrous metals. The discussion applies the conclusions of Noesen's paper to the vacuum arc melting of steel. It is concluded that elimination of impurities due to strong superheating of the melt seems unlikely in the pool or the arc gap, but may occur at the electrode tip. Degree of purification may be increased by increasing the vacuum over the melt and electrode surfaces; this can best be done by reducing the gas-flow impedance of the crucible-electrode configuration.

Vacuum treatment of converter steel P. Ya. Sorokin (*Stal'*, 1960, (11), 988–991) Comments on an article by A. M. Samarin *et al.* in *Stal'*, 1953, (3). It is claimed that ladle vacuum treatment does not produce uniform degasification throughout the charge. Flushing with inert gases is said to be much more effective. Other criticisms of the original article are made.

Mechanical properties of AISI 4340 steel improved by consumable electrode vacuum remelting S. Cvikevitch (*WAL–TR*–310–1/1; 1959, Sept., pp.55; from *Nucl. Sci. Abs.*, 1959, **13**, Dec. 31, 3001–3002) An investigation of the effects of vacuum remelting by the consumable electrode process of aircraft quality AISI 4340 steel which was originally melted in the basic electric furnace is described.

Iron strips for vacuum technique E. Nagy (*Koh. Lapok*, 1960, **93**, Jan., 1–5) In order to replace Ni in vacuum valves, the iron must be practically free from O, S, P, and C. The production of such high-purity iron strips of 0·14 mm × 190 mm is described.—P.K.

The production of high-purity iron W. A. Fischer and A. Hoffmann (*Stahl Eisen*, 1960, **80**, Oct. 27, 1497–1501) The various stages in the production, melting, and remelting in air and vacuum, are described. In induction vacuum melting, the oxygen in the iron was eliminated by carbon addition, but this stage was followed by a second vacuum melting. Melting time *in vacuo* should be kept as short as possible to avoid Si pick-up. Analysis showed that the final product contained not more than 0·005%C, Si, P, Si and Al, not more than 0·003%O, and not more than 0·002%Mn and N (31 refs).—T.G.

Vacuum remelting and casting (*Proc. Met. Mold.*, 1960, **18**, May, 46–47) The increasing importance in investment casting of vacuum melting and casting is emphasized in obtaining improved alloy properties. The operation of a typical remelt and investment casting process is described and illustrated.

Large vacuum furnace to heat treat ICBM parts (*Steel*, 1960, **147**, Aug. 1, 85) A furnace capable of operating at 2250°F and processing high alloy steels used in making the Atlas is briefly described.—S.H.-S.

Vacuum casting of steel K. Sugazawa, S. Yamada, and H. Matsuoka (*Sumi Met.*, 1959, **11**, Oct., 252–260) Data are given for five months' operation of a vacuum casting unit with a steam-ejector pump system, handling 80-t ingot castings. Removal of H_2, O_2, and N_2 was 70, 40, and 10% respectively. Sensitivity to flaking was much reduced. Non-metallic inclusions (Al_2O_3) decreased. Results of the ultrasonic test for forging steels were much improved.—K.E.J.

Vacuum casting process of steel. No.2 M. Yoshida (*Denki-Seiko*, 1959, **30**, May, 279–300) [In Japanese]. —K.E.J.

Vacuum arc-melting furnace adapted for ultrasonic grain refinement in large ingots Westinghouse Corp. (*Ind. Heat.*, 1960, **27**, July, 1394–1552) The addition of a transducer assembly gives metal with an equiaxed structure and improved mechanical properties. The furnace produces ingots up to 2000 lb in type 316 stainless, rotor steel, Refractoloy and Discalloy.—K.E.J.

Steels of much higher strength appear feasible metallurgically W. R. Patterson (*Ind. Heat.*, 1960, **27**, July, 1438–1442) An historical article, tracing the improvements in steel properties since the nineteenth century, predicts strengthening of steel beyond 300 000 lb/in² by controlled additions of alloying elements during vacuum melting.—K.E.J.

REHEATING FURNACES AND SOAKING PITS

Non-oxidizing heating of steel in open-flame furnaces V. A. Kurocdov (**Kuznechno-Shtampov.*, 1959, **1**, (1), 25–31) Using specially designed regenerators and burners, attaining air-preheat of 900°C, and regulating the air supply, billets for forging were heated to forging temp. of the order of 1200°C without scaling. Details of the calculations and of the design of the regenerators and burners are given.

Application of flow research to industrial furnaces, with particular emphasis on soaking pits H. Boenecke (*JISI*, 1961, **197**, April, 283–295) [This issue].

The scaleless heating of steel in industrial furnaces J. Goczal (*Hutnik*, 1960, **27**, (4), 142–144) This work is based on articles in *Ind. Heat.*, and *Iron Coal Trades Rev.*, 1957. It considers the various methods now in use to limit oxidation during heating.

Alloy steel recuperators preheat soaking pit air (*Steel*, 1960, **146**, June 13, 166) The use of Escher recuperators by H. K. Porter Co. Inc. is described. Minimum maintenance and long life (up to ten years at peak efficiency) are expected. Air preheat is 1000°F.—D.L.C.P.

ELPIT—the electric soaking pit G. Schjeldcrup (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 382–392) A description of the construction, operation, applications, and economics of the four types of ELPIT electric soaking pit manufactured by Christiania Spigerwerk, Norway.

Thermal problems of induction billet heating. III R. M. Baker (*Ind. Heat.*, 1960, **27**, July, 1374–1378) Further discussion is presented of the analytical equations and their application to practical heating problems. Methods of temp. equalizations are considered in detail. The information given allows a heating line to be planned up to the point of designing the induction-heating coils.—K.E.J.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

Design and heat treatment F. Strasser (*Iron Steel*, 1960, **33**, June, 341–345) The author gives advice on avoiding difficulties by correct press tool design. He deals first with the selection of steel then the criteria for good design and suggests solutions for typical design problems. Special reference is made to the advantages of composite construction of die plates and problems connected with punches and bending dies.

Recent heat treatment furnace installations: annual survey of developments (*Metallurgia*, 1960, **71**, June, 247–268) A review of recent installations and their applications, with illustrations.

Oil burners in metallurgy A. Roos (*Métal. Constr. Mécan.*, 1960, **92**, Sept., 683, 685, 686, 689, 691–693, 695–696) A classification of burners is presented: comprising air or steam draught and mechanical draught. Miscellaneous metallurgical uses are described, illustrated and discussed, with a concluding section on the results of the operation of revolving hearth furnaces.—S.H.-S.

How to prepare an economic study on heat processing furnaces B. A. Ruediger (*Foundry*, 1960, **88**, Aug., 170, 172–175) A study with examples is presented.—S.H.-S.

Atmosphere-generator produces high-purity nitrogen Lindberg Engineering Co. (*Iron Age*, 1960, **185**, June 9, 108–109) A 'Hyni' completely automatic unit for producing 99·99% pure N_2 for furnace atmospheres is described. Gas is burned under controlled conditions in a catalyst combustion chamber, and is then passed through a 'molecular sieve' absorption tower where CO_2, H_2O, S, H_2S, and traces of nitrogen oxides are removed. The absorbent is regenerated using preheated air.—D.L.C.P.

Protective gas and plant for its manufacture P. O. Strandell (*Jernkont. Ann.*, 1960, **144**, (6), 444–478) Reactions between furnace atmospheres and metal surfaces are discussed, types of controlled atmospheres used in furnaces are outlined and generators described. The problem of the safe operation of furnaces using explosive atmospheres is considered (36 refs).

Heat-treatment of Mn–V–Mo age-hardening austenitic steel N. C. Howells and E. A. Lange (*NRL*–5464, 1960, Feb., pp.10; from *Nucl. Sci. Abs.*, 1950, **14**, Oct. 15, 2485) The age-hardening characteristics of Mn–V–Mo austenitic steels were determined as a function of the temp. of solution treatment. The optimum condition for developing the full age-hardening potential of an alloy is ½ h at 2100°F followed by a water quench. Subsequent ageing treatments required for maximum hardness levels are: 1 h at 1400°F, 6 h at 1300°F, or 16 h at 1200°F. An ageing temp. between 1200 and 1300°F is optimum for controlling the balance between yield strength and ductility. The yield strength of metals in the fully-aged condition is directly proportional to Brinell hardness, at 80 000 to 150 000 psi for the compositions investigated.—C.F.C.

Study on austempering of structural special steels. IV. Effect of heat-treatment on the mechanical properties of Ni–Cr–Mo and Cr–Mo structural steels H. Hotta (*Nippon Kinzoku*, 1959, **23**, Dec., 712–716) Data are given for hardness, tensile strength, microstructure, austenitic grain size, etc. Good test results at room and high temp. were obtained with Cr–Mo steel austempered at 350°C for 30 min.

Variety of heat treating facilities at new Ford plant A. Q. Smith (*Ind. Heat.*, 1960, **27**, July, 1416–1422) Details are given of the equipment at the Ford Indianapolis plant for treating parts for steering units. It includes four Holcroft radiant-tube continuous carburizing, quench and draw furnaces, two Dow radiant-tube prepared-atmosphere batch furnaces, a surface combustion rotary hearth furnace, a Holcroft furnace for carburizing to 0·065 in, and three salt-bath furnaces.—K.E.J.

High temperature carburising. I W. H. Holcroft (*Ind. Heat.*, 1960, **27**, Aug., 1596–1608, 1612) Particulars are given of carburizing equipment developed for operation up to 1850°F, or, if necessary, 2200°F; this is based on wartime needs for deep cases on low alloy steels. Data are given for carbon penetration and penetration rates for various temp. in varying atm. To avoid high surface carbon contents, carburizing is best done for a period at high carburizing potential followed by a surface decarburization treatment. Photomicrographs show typical results.—K.E.J.

Development and properties of directly hardenable case-hardening steels H. Tauscher and E. Stecher (*Neue Hütte*, 1960, **5**, Oct., 596–607) Case-hardening is discussed with special emphasis on the difficulties arising from the hardening processes. The use of steels which have still to be developed is suggested and for which Mo is the best alloying addition, requiring one hardening treatment only, hence the name 'directly hardenable'. The special requirements of the properties of these steels are summarized and tests on carburizing, static, and dynamic behaviour of an experimental steel with 0·20%C, 0·35%Si, 0·68%Mn, 0·024%P, 0·019%S, 0·39%Cr, and 0·65%Mo are reported.

Vertical furnaces heat treat generator rotors (*Met. Prog.* 1960 **78**, Aug., 115–116) Furnaces installed at the Homestead Works of United States Steel Corp. for heat treating rotors and generators 40 ft long and 60 in. dia. are described.

Heat treatment of metals in oxygen-free media P. D. Gavrilov (*Metallov. Obra. Met.*, 1959, (2), 59–60) Materials are heated in hermetically sealed containers containing Na to absorb atmospheric O_2.

Avoiding component failure by correct design. Heat treatment and service conditions A. G. Gardner (*Mech. World*, 1060, **140**, June, 230–234) The importance of correct design in minimizing stress during heat treatment and subsequent service, and how quenching technique can influence internal stress are exemplified and reviewed.—S.H.-S.

Increasing furnace refractory life by means of resilient furnace mountings S. L. Perlow (*Ind. Heat.*, 1960, **27**, April, 828–832) Damage from external vibration is reduced by mounting complete furnace installations on Korfund steel-spring units. Their use with a 30-ft rotary hearth furnace and a 35000-lb heat-treating furnace is described. Lives of furnace arches and tops may be increased 2½ or 3 times.

New heating element alloy for controlled atmosphere furnaces F. S. Sibley (*Ind. Heat.*, 1960, **27**, May, 982–992) Details are given of the development and properties of Chromel-AA, suitable for use up to 2150°F which is an 80:20 Ni–Cr alloy modified by additions of Fe, Si, Co, Mn, and Nb. Compared with standard Ni–Cr and Ni–Cr–Fe alloys, it has better resistance to C pick-up and corrosion in reducing atm., and is resistant to attack by S, Cl, etc. It is not susceptible to 'green rot'. Data are given for converting furnaces to the new elements.—K.E.J.

Thermomechanical treatment of steels 15M and 12MKh A. P. Simakovskii (*Metallov. Obra. Met.*, 1959, (2), 40–44) These steels are used in the Soviet Union for the manufacture of tubes and collector vessels for high-pressure steam plant. Tests carried out simulated the manipulation and heat treatment to which the materials are subjected during manufacture and fabrication. The steels investigated had the compositions (12MKh) 0·18%C, 0·30%Si, 0·52%Cr, 0·37%Ni, 0·48%Mo, and (15M) 14–15%C, 0·25–0·33%Si, 0·49–0·57%Mn, 0·27–0·34%Cr, and 0·42–0·46%Mo.

Cooling of forgings from steel susceptible to flaking E. S. Tovpenets (*Metallov. Obra. Met.*, 1959, (2), 7–13) The slow rate of cooling necessary for these steels is accelerated by the fluctuating cooling regime described, in which large forgings are cooled in a total time of 72–170 h. Transformation of supercooled austenite is accelerated (12 refs).

Experiences with salt bath containers B. Finnern (*Härt. Techn. Mitt.*, 1960, **15**, 41–44) The life of salt bath containers is discussed in relation to their method of manufacture and mode of heating the bath. External heating results in more wear than in internally heated types.—R.P.

Temperature distribution in salt baths H. Ornig (*Härt. Techn. Mitt.*, 1960, **15**, (1), 106) It is shown that temp. variations within a salt bath are greater than expected. The position of maximum temp. depends on the method of heating. Stirring results in a more even temp. distribution.—R.P.

Mechanized installations for salt-bath hardening E. Zeitz (*Härt. Techn. Mitt.*, 1960, **15**, (1), 107–114) The paper describes various kinds of fully automatic and semi-mechanized hardening installations capable of dealing with a variety of materials.—R.P.

Rapid heating of heavy forgings J. Zlatníková and I. Zlatník (*Hutník*, 1960, **10**, (8), 311–314) The problem of the maximum permissible heating rates in large forgings re-heated prior to hardening is discussed with special reference to rotors weighing about 20 t. Considerably higher rates of heating then those commonly used were found to be without adverse effects, and could be used with almost all simpler forgings of low and medium alloy steels.—P.F.

An investigation of special treatment for developing high toughness in ultra high-strength steels C. W. Marshall, G. W. Form, and R. F. Hehemann (*AD* 211011; *WAL* 310/214; *PB* 144878, 1958, Nov., pp.56; from *US Res. Rep.*, 1960, **33**, May 13, 544) A new hardening technique to yield pronounced improvements in strength and toughness. Working temp. and amount and mode of deformation prior to quenching were investigated and deformation of austenite prior to quenching did not invariably improve mechanical properties.—S.H.-S.

The production of cases of maximum hardness by heat treatment in boron-containing media O. Schaaber (*Härt. Techn. Mitt.*, 1960, **15**, 44–48) The production, properties, and uses of boron-treated cases on steel parts are described. Liquid or gaseous media can be used. The case obtained is 150–250 μ thick, very hard, but brittle. Boron diffusing into steel surfaces forms a definite compound with the metal; under certain conditions $Me_nB_mC_p$ compounds may form (26 refs).—R.P.

Method for determining the start of martensite formation when hardening cased structural parts O. Fischer (*Härt. Techn. Mitt.*, 1960, **15**, 87–88) The author suggests a graphical method for determining the Ms and Mf in the case of a 0·18%C steel, the case depth in the given example being 2 mm and the carbon content of the case 1·1%. The inaccuracy of the method is pointed out.—R.P.

Fundamental studies of gas carburizing. Part II W. T. Groves (*Tratt. Term. Met.*, 1960 **3**, May–June 9–17) This second article in the series on the theory and practice of gas carburizing contains a layout diagram showing the distribution of the controlled atmosphere by automatic regulation of the carbon concentration, using the dew-point method in a four-temp. zone carburizing furnace in operation at the Dana Corporation.

New process alloys steel while in coiled form L. Wilson (*Iron Age*, 1960, **186**, July 7, 73–75) A new open-coil process of gas alloying of coiled strip with its applications including the production of ultra-low carbon and nitrogen steels at great savings, and claimed as one of the most significant advances in steelmaking in more than a decade, is presented.—S.H.-S.

Tests with ^{14}C regarding the transfer of carbon from molten salts containing cyanide to iron H. Ornig (*Härt. Techn. Mitt.*, 1960, **15**, 1–14) Using ^{14}C, it was shown that only cyanide is likely to give up carbon to iron between 500 and 550°C in atmospheres containing CO and CO_2, the melts used containing cyanide, cyanate, and carbonate. Exchange of carbon atoms between cyanide and carbonate and between cyanide and cyanate was investigated (31 refs).—R.P.

Pump parts heat-treated in large pit type furnaces Fluid Packed Pump Co. (*Ind. Heat.*, 1960, **27**, May, 938–944) Versatility of treating plain-carbon and nickel steels for oil-well pump equipment is provided. Endothermic gas carburizing is used, the generator giving a cracked natural gas-air mixture, which is substantially a N_2–CO–H_2 mixture whose composition is stabilized. Atm can be generated for correction or restoration of carbon, and for protection during tempering or brazing. The generator feeds vertical gas and electric furnaces, and salt-bath and pack carburizing equipment is also operated.—K.E.J.

The effect of preheating on residual stress in surface flame hardening H. Bühler (*Härt. Techn. Mitt.*, **13**, (2), 115–131) Tests on various steels are described. It was found that for the same type and diameter of the surface hardened steel test pieces, the hardness depth attained is of decisive importance for the type of residual stress distribution and the extent of residual stress in the core. In the case of low hardness depth, residual stress conditions are produced with compressive stress in the peripheral zones and in the core and tensile stress in a circular zone lying in between. With enlargement of the hardness depth created in surface hardening the compressive stress in the core becomes tensile stress and at increased hardness depth reaches considerable values whereas the compressive stresses in the peripheral zones are not affected to the same extent by the increase in hardening depth.

Inductive carburization of Armco iron in liquid media A. Moszcynski (*Härt. Techn. Mitt.*, 1960, **15**, 50—51) The influence of time and temp. on the thickness and structure of the carburized layer are discussed. Methyl alcohol is considered to be a better carburizing medium than ethyl alcohol or petrol. The case thickness produced is the same as that obtained by gas carburizing at the same temp.—R.P.

Flame hardening of nodular cast irons F. A. Caudle and V. De Pierre (*NAVORD Rept.* 6506; *NWPW–T–16–59*; *AD–226028*; *PB* 143886, 1959, Aug., pp.28; from *US Govt. Res. Rep.*, 1960, **33**, Feb. 12, 193) The procedure described for surface hardening ferritic nodular irons consists of multiple flame passes followed by water quenching, and produces a surface hardness of Rockwell C50–58, with case depths of 0·03–0·07 in. A literature survey on the flame-hardening of cast irons is included (55 refs).

The surface alloying of steel and pig-iron castings with sulphur M. I. Furman (*Lit. Proizv.*, 1960, (10), 43–44) Liquid, solid, and gaseous methods of the sulphiding thermal-diffusion saturation of the surface of castings with sulphur are reviewed. It is pointed out that the layer obtained is only 0·1–0·5 mm thick and that therefore the castings must be ready for use without machining. Sulphiding in the mould should be investigated.

On the sulphurization of cast iron at high temperatures H. Nakai (*Tetsu to Hagane*, 1960, **46**, June, 652–657) Experiments were made in a stream of hot H_2S. The sulphurization product, as with steel, is a mixture of pyrrhotite and pyrite. In the outer layer, C and P do not diffuse; Mn diffuses freely and Si slightly. Equations are given for the sulphurization rate and its variation with temp. The iron structure has no effect on rate; C increases it, but Si and Mn do not (18 refs).—K.E.J.

Mechanical positioner solves heat treating problem Ohio Crankshaft Corp. (*Steel*, 1960, **146**, June 13, 156–157) A device for positioning a casting for induction heating is described. The casting tolerance is too great to allow jig-positioning of the part. Instead, the part is held on a rotating table in a fixture that is positioned hydraulically by a scissors arrangement which sets the desired spacing from the induction coil.—D.L.C.P.

Prespheroidizing of high speed steel: change of structure by heat treatment alone (*Metallurgia*, 1960, **62**, Sept., 100–102) A summary based on four BISRA reports in which it was shown that in a prespheroidizing treatment of the as-cast ingot, the carbide is broken up before hot working.

Modern heat treating helps firm compete Empire Plow Co. (*Steel*, 1960, **146**, June 6, 116–118) Two lines for the isothermal heat-treatment of replacement parts for agricultural equipment are described. This treatment imparts a good combination of hardness and ductility to 0·8%C steel for soil-working components. The sequence includes an austenitizing salt bath, a quenching salt bath, a tempering furnace, and a washing station.—D.L.C.P.

Heat treating variety of gears requires flexible facility J. Lotter (*Ind. Heat.*, 1960, **27**, July, 1382–1392) Full details are given of a new, compact installation for treating a large variety of gears to different specifications. It includes two Super Allease controlled-atmosphere furnaces, a Fore–Aire horizontal convection furnace, a temp.-controlled spray washer, DX and RX gas generators, and an automatic dewpoint control system.—K.E.J.

Continuous cycle heating–cooling furnace provides better structure control in annealing for machining A. G. Sturrock (*Wire Wire Prod.*, 1960, **35**, March, 340–342) The use of a 70 ft roller hearth furnace for achieving a consistent and uniform structure in carbon steel bar stock is described. The furnace has six chambers for heating or cooling and a choice of atmospheres so that accurate control of the steel structure is possible.—D.L.C.P.

A new application for salt bath treatment of eutectoid steel E. W. Stotz (*Iron Steel Eng.*, 1960, **37**, July, 125–130) Existing tempering furnaces for rail anchors were replaced by salt bath furnaces with automatic drive, saving space, labour, and cost of equipment, and giving an improved product.

Electric furnace for annealing stainless coils (*Brit. Steel*, 1960, **26**, March, 96–97) An account of the construction and operation of the four bell-type electrically heated furnaces installed between 1953 and 1959 at the works of Shepcote Lane Rolling Mills Ltd, by G. W. B. Furnaces Ltd.

Continuous annealing line to help tin plate users (*Steel*, 1960, **146**, June 27, 80) The new continuous annealing line of Jones & Laughlin Steel Corp. is described. It processes steel strip at speeds up to 2000 fpm. Material passes through the line in less than 2 min. An electronic computer will record operating data and will eventually regulate temp. and speed variables.—D.L.C.P.

Bright annealing stainless steel strip in high production furnace of advanced design (*Ind. Heat.*, 1960, **27**, July, 1432–1436) A vertical electrical furnace made by G.E.C. has many new design principles. Bright annealing is done using direct radiant heating with Mo elements jet cooling, and protective atm. The jet cooling units comprise water-to-gas heat exchangers and fan assemblies. Strip widths of 12, 24, 36, and 48 in can be treated at a typical rate of 6000 lb/h.—K.E.J.

Computerized control of a continuous annealing line R. H. Smith (*AISI preprint*, 1960, pp.19) An account of the Aliquippa works continuous annealing line claimed to have the first digital control computer system, the first package control system, and the first processing line tensiometer regulators. Plans for increased computerised operation are discussed.

Structural changes in the heat treatment of iron–graphite materials H. Wiegand and H. Hentze (*Giesserei Techn.-Wiss. Beih.*, 1960, July, 1629–1638) By means of the two methods described, measurements were made on selected iron–graphite materials, which threw light on the characteristic structural changes in these materials in important industrial heat treatments. Lamellar and nodular irons were examined by long-time and short-time heat-treatment (end-quench test) (32 refs).

FORGING, STAMPING, DRAWING AND PRESSING

Advanced methods for forming metals W. S. Hollis (*Engineering*, 1960, **190**, July 1, 25–26) A review of advances in forging, explosive forming, hydroforming, sheet cold-forming, and impact extrusion.

Basic technology of hot forging Ya. M. Okhrimenko (Ed. by S. Ya. Golovin (*Osnovy Tekhnologii Goryachei Shtampovki*, Moscow, 1957; 60–19103, 1060, Jan., pp.382; *F–TS–9650/V*; from *Nucl. Sci. Abs.*, 1960, **4**, Sept. 4, 281) This work is intended as a textbook in the special course 'Hot Forging' for students specializing in 'Forging Production' at Metallurgical Colleges. It may also be used by production personnel.

The importance of research for the technical and economic development of plastic forming G. Wallquist (*Jernkont. Ann.*, 1960, **144**, (7), 481–519) A review of work carried out at the Royal Institute of Technology, Sweden in this field while the author was professor at the Institute (94 refs).

Towards automatic forging: progress of B.I.S.R.A. research project BISRA (*Metallurgia*, 1960, **62**, Sept., 108–109) The BISRA research programme and results so far achieved are outlined.

Can the small forger compete with automated shops? D. Clark and G. Ruicci (*Iron Age*, 1960, **185**, June 9, 101–103) The results of a study by a small forging company are described. It was concluded that small drop forging shops can compete with mass production shops provided modern techniques are employed and maximum capacity is utilized. One gain results from longer die-life in drop hammer operations compared with an automated line. By ensuring that metal is kept moving under every blow of the hammer, scale-free forgings are produced.—D.L.C.P.

The contributions made by German steel works to the development of large forgings H. Gummert (*Stahl Eisen*, 1960, **80**, Oct. 27, 1517–1524) A review of the evolution of German forging techniques from the steam-hammer to the forging press is presented. It is interesting to note that the introduction of vacuum-cast ingots reduced the requirements of the forging presses. For this reason the new forging presses acquired during the rebuilding of the German industry after the war are mostly of medium size. Only two presses of 6000-t capacity have recently been put into operation.—T.G.

The forging of heat-resisting steel F. M. Valyavkin (*Kuznech. Proizv.*, 1960, (7), 8–13) High-alloy, stainless, heat-resisting, and other special steels and alloys have certain special features of hot plastic working, one of which is low permissible degrees of deformation. Low ductility limits the possibilities for working these materials, and lowers their effectiveness from the standpoints both of productivity and of metal consumption. Types Kh23N18 and EI417 steels were thoroughly studied with a view to overcoming these disadvantages.

Transformation characteristics of large steel forgings S. Onodera and A. Tokuda (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 483–488) An account of work carried out at the Japan Steel Works Ltd on the isothermal transformation characteristics of several large forgings, together with comparative tests on two ingots with different solidification rates of the effects of solidification rate, forging, and soaking.

Drop forging the liquid metal I. Dragan (*Met. si Constr. Masini*, 1960, **12**, (6), 495–499) In forging hot metal, parts can be produced with a ratio of length to thickness much greater than when casting under pressure in metal moulds; the structure is fine, the walls are very dense and mechanical properties approach those of die-forged components. Machine parts without external flanges perpendicular to the direction of the advancing mandrel, can be produced without difficulty and probably also motor engine pistons.

High energy rate metal forming: Summary of high strength steel and titanium alloy sheet products M. Titinsky (1958, March). **Tentative analysis of some problems of forming with explosives** (*MAS–56*) W. Schroeder. **Practicability of detonation and shock wave analysis for high energy rate forming** K. G. Eckel (1958, Feb., *MAS–57*). **III. Chemical and physical properties of powders, propellants and high explosives. IV. Discussion of theoretical differences between statically and dynamically (impulsively) applied loads. V. Bibliography** (*LR* 12970 and *LR* 12957; *AD–156722*, pp.191; from *Nucl. Sci. Abs.*, 1959, **13**, Nov. 30, 2705–2706) An investigation into the application of high rates of energy to the forming of materials difficult or impossible to form by conventional means is presented. 27 organizations were contacted. Their methods of applying high velocity energy and hydrostatic pressures have been examined to establish the best method for production use.

Explosive forming of refractory metals R. L. Wachtell (*AD–231924*, 1959, Sept., pp.50; from *Nucl. Sci. Abs.*, 1960, **14**, Oct. 15, 2492) Die and firing fixtures were completed and put into use. Detonations were carried out using pure Mo, ½%Ti–Mo alloy, and 17–7 PH stainless steel. Three different explosives were used, with two transmission media and two temp. The results indicated that Mo and ½%Mo–Ti alloy do not form satisfactorily at ambient temp. under the conditions used. However, at 200 to 212°F substantial elongation and plastic deformation occurred and much better forming was achieved. Tensile strength, yield strength, and elongation measurements made on the first lot of Universal Cyclops ½%Ti–Mo are presented.

Development of high temperature die materials (hot die materials) H. R. Nichols, W. H. Graft, V. Pulsifer, and P. R. Gouwens (*AMC–TR–59–7–579*; *AD–232717*, 1959, June pp.133; from *Nucl. Sci. Abs.*, 1960, **14**, Sept. 30, 2315) Steel forgings were made in hot dies of Inconel 713–C using KI-graphite as lubricant-parting agent. This was superior to other alloys tested.

Automatic hot forging of nuts (*Wire World Internal*, 1960, **2**, June, 127–128) A description of an automatic hot forging machine is given and its advantages as compared with stamping from hand fed rectangular bar are listed. The various stages of the process are given.

The mass production of threaded studs E. Lick:eig (*Wire World Internat.*, 1960, **2**, June, 121–127) The equipment and methods used in the automatic production of threaded studs are described.

High speed forming of metal plates: one-twelfth scale tests with explosives (*Metallurgia*, 1960, **62**, Oct., 144–145) A description of trials carried out by Vickers–Armstrongs (Engineers) Ltd on a small-scale model of the dome end of a pressure vessel, using blanks of 20 swg bright mild steel plate. Promising results were obtained.

Press design makes forge shop versatile Allegheny–Ludlam Steel Corp. (*Steel*, 1960, **147**, Aug. 22, 30–31) A two-column inverted forging press is described which is claimed to handle ingots of low and high alloy steels, high temp. alloy steels, stainless, Ti, and other metals weighing up to 15·t and measuring up to 40 in square, and a variety of advantages are suggested for its operation.—S.H.-S.

Determination of compressive force chipless deformation on multistage cross-travel cold presses A. Wolf and B. Hatebur (*Draht*, 1960, **11**, May, 234–240) Experimental equipment is described for determining the compressive power in presses for the manufacture of bolts.

Pipe-sections press for steel components V. I. Kopitsyn (*Vestnik Mashin*, 1960, (6), 34–35) A press of type P–667 for different pipe shapes is described. Its main characteristics are: total force 3595 t; maximum speed 300 mm/s; overall dimensions: dia. 270 mm, length 900 mm. Hydraulically driven, operating with a pressure of 320 kg/cm² and has also a number of auxiliary mechanisms.

Difficulties in punching thick and hard steel sheet G. Oehler (*Werkstattstechn.*, 1960, **50**, Nov., 582–586) New research showed that the rule to use a small gap between punch and die is valid only for rather thin and not too hard steel sheet. When using hard and thick sheet the material tends to tear at the cutting edge. Another difficulty, the formation of a built-up edge, can usually be overcome by lubrication, correct cooling and alignment of the tools.

Influence of size of blanking diameter in shearing operations on sheet metals T. Maeda and K. Tamura (*Bull. JSME*, 1960, **3**, 312–319) Circular blanking tests of 2 to 50 mm dia. with a mild steel sheet, a copper plate, and an Al plate 0·2 to 1·0 mm thick are reported, as a result of which the process has been classified into two sorts, according to the ratio of die hole to metal thickness: i.e. a narrow punching process and a general blanking process.

The bending of internal rims with dies R. Wilken (*Forsch. Wirts. Nordrhein–Westfalen*, 1959, (794), pp.80) The mechanism of the forming process is examined, and the influence of tool design discussed (18 refs).

Tests for defining drawability J. Pomey, A. Royez, and P. Dhez *Rev. Mét. Mém. Sci.*,

1960, **57,** Oct., 741–754) Three methods are described—tension on a large specimen, biaxial Jovignot hydrostatic elongation, and a modified Guyot test, one of which is sufficient in a given case to define deep-drawing capacity. A practical cupping test is also proposed. The selection of the correct lubricant is discussed.

Determination of the material stressing and compressive power for deep drawing and stretch-reducing with various drawing ratios H. Mäkelt (*Mitt. Forsch. Blechverarb.*, 1960, March 1, 50–55) A method is developed for determining graphically and by calculation the stresses occurring in deep drawing and stretch reducing, and the compressive power required, without knowing the mean deformation work.

Graphical method for determining forces and power requirements in drawing bars and tubes H. Mäkelt (**Industrie-Anzeiger*, 1959, May 19, 28–31) With the graphical method described requirements both for simple and for multiple drawing processes can be calculated. The results, sufficiently accurate for practical purposes, have been confirmed by experiments on draw benches.

New ways in the design of plate and section stretching machines A. Hertl. (*Z. Metallk.*, 1960, **51,** Oct., 555–560) These stretching machines are used not only for straightening but also for strain-hardening purposes. If the plates or sections are strained above the proof stress, unevenly distributed internal stresses are removed, i.e. the plate will not warp after machining. For shipbuilding, chemical plant construction etc. the use of straightened, strain-hardened and stress-free plates is of great importance. The author describes a plate stretcher of 15 000 (short) t capacity and a bar stretcher of 1 100 (short) t capacity. Both machines were built in Germany for USA.

The effect of the microsurface on the behaviour of sheet in deep drawing F. Fischer, K. H. Schmitt-Thomas, and V. Seul (*Stahl Eisen*, 1960, **80,** Oct. 27, 1524–1531) The mechanism of working in deep drawing with special reference to the properties and shape of the microsurface is discussed. It was found that a surface that consists of a very large number of slim projections which are evenly distributed over the whole surface are best for the deformation process in the die during deep drawing. These projections should be as soft as possible for easy deformation and turning into the direction of working in the die (26 refs).

Hydraulic bulge tester determines sheet drawing quality W. N. Lambert, E. S. Madrzyk, and F. E. Gibson (*J. Met.*, 1960, **12,** Nov., 857–860) It is shown that it is possible to utilize the instability point of a metal under biaxial tension as a sensitive criterion of drawability (19 refs).

New extrusion processes (*Draht*, 1960, **11,** Oct., 645–648) This is a review of US practice for the production of clad extrusions. This process has not been applied in Europe. It is pointed out that present experience showed that the press constants of the two materials extruded together should not differ by more than 25%. A diagram showing these press constants is included in the review.—T.G.

Steel and specialty alloy extrusions (*Prec. Met. Mold.*, 1960, **18,** May, 49–50) Small orders for steel and stainless steel shapes in continuous lengths up to 60 ft can be most economical when made by extrusion. A guide is given which provides design and tolerance data.

Fabrication history of Universal Cyclops B^{10}-stainless steel ingot KB 918 S. M. Bishop and W. J. Gregg (*KAPL–M–SMB–4*, 1958, June, pp.7; from *Nucl. Sci. Abs.*, 1959, **13,** Jan. 15, 26) Extrusion of the ingot into wire is described in detail.

Extruded steel sections save man-hours (*Metalw. Prod.*, 1960, **104,** Aug. 10, 55) The use of the Urgine Séjournet process, in which glass is applied as a lubricant and insulating medium, with a Loewy 1150-t three-stage horizontal extrusion press at the Sheffield works of Samuel Osborn & Co. Ltd, has made possible the hot extrusion of all qualities of steel (including heat-resisting alloys and stainless) to close tolerances and with diminution of machining. The process is briefly discussed.—S.H.-S.

ROLLING MILL PRACTICE

Rolling mills and rolling-mill practice A. Wolf (*VDIZ*, 1960, **102,** Nov. 1, 1492–1499) This is a review of information on rolling mills and rolling-mill practice which has been published during the last few years dealing with: output figures, new plants, research, hot rolling, wide-strip rolling, and miscellaneous, powder rolling, combined continuous casting and rolling processes, wire rolling, and prestressed rolling stands (131 refs).—T.G.

Methods for removing surface defects from raw material intended for rolling M. Tylusinski (*Hutnik*, 1960, **27,** (5), 182–188) The methods of surface cleaning are first examined, in particular mechanical and electro-pneumatic methods. The article concludes with the examination of flame-cleaning and flame-cleaning with the aid of machines.

The influence of additional friction in simple die rollers Z. Wusatowski and J. Ludyga (*Arch. Hutn.*, 1960, **5,** (2), 195–242) In order to determine the mean resistance to deformation in the grooves, the authors found Siebel's method to be insufficiently accurate, and carried out extensive investigations to obtain more accurate results. In these investigations other parameters such as shape, temp., and draught were considered. The results are given in the form of numerous graphs.

Bending tools (*Métal. Constr. Mécan.*, 1960, **92,** Sept., 665–666, 669, 671–673) Bending machines and presses are described and illustrated, and tooling tool fitting, and the selection of tools are discussed.—S.H.-S.

A new electrical circuit for reversing dynamic braking control of mill type d-c series motors K. S. Kuka (*Iron Steel Eng.*, 1960, **37,** July, 113–124) The circuit described provides dynamic braking control, and uses heavy duty silicon rectifiers.

An increase in the productivity of rolling mills E. A. Svetlitskii and B. I. Mindlin (*Metallurg*, 1960, (10), 30–31) An increase in the angle of inclination of the working rolls of rolling mills increased rolling speed and eliminated bottlenecks at the Zakarkazkii works. In addition, after the automation of the front and rear tables, the time taken for auxiliary operations was much reduced.

Formulae for determining metal pressure on the rolls during the process of rolling (*Stal'*, 1960, (11), 1012–1013) A summary by the editors of aspects of the communications of Yu. M. Chizhikov and A. I. Tselikov in *Stal'*, 1958, (5), with criticisms received.

Joints for spindles of rolling-mill drives A. Schulz (*VDIZ*, 1960, **102,** Nov. 1, 1460–1463) The various types of joints, mostly of the universal type, are described and illustrated, and the main features for aiding in the selection of such joints are stressed. They are grouped under the headings: dry joints, oil-bath joints, quick-release joints, and special joints, including one that breaks in case of overloading.

The causes of the skewing of bloom faces and of their distortion during rolling N. F. Gritsuk and S. V. Merekin (*Metallurg*, 1960, (10), 24–27) Rolling on blooming mills is frequently accompanied by the skewing of ingot faces on the smooth part of the rolls and by the bending of blooms during rolling in the grooves. The various causes of this are considered.

Newest structural mill debuts (*Steel*, 1960, **146.** May 30, 76–78) The new automated mill for structural sections at South Works of US Steel Corp. is described. The blooming and breakdown mills can be controlled by punched card programmes. The first finishing stand is manually controlled, and the following three follow accordingly. Any four of 13 different stands can be installed in this line in a few minutes by crane, so that products can be varied rapidly.—D.L.C.P.

The shaping by grinding of rolls for the hot rolling of sheet and wide strip H. Winterkamp and K. Herwig (*Stahl Eisen*, 1960, **80,** Oct. 13, 1424–1426) The authors report and discuss the method of calculation of roll surfaces in the hot rolling of sheet and wide strip as developed by J. Mercáder. Bending of the rolls and different thermal expansion in the centre and the edges affect the shape of the roll barrel in hot rolling and therefore the profile of the roll gap. The method of calculation of Mercáder is compared with those of Larke, Caswell, and Emicke.

The use of oil film bearings on a 12 inch merchant mill H. S. Baldwin (*Iron Steel Eng.*, 1960, **37,** June, 111–116) The mill layout and the lubrication system are described, and an account is given of the maintenance of the oil systems and of the causes and solutions of troubles encountered. The combination of closed top housings and oil-film bearings has enabled rolls to be removed and new ones installed in 5 min.

Acme Steel installs 32-in blooming mill at Riverdale (*Iron Steel Eng.*, 1960, **37,** June, 141) The equipment of the mill is described.

A study of the rolling process on the two-high roughing stand of the 2350 medium sheet rolling mill at the Magnitogorsk Combine N. M. Lapotyshkin (*Stal'*, 1960, (10), 935) A note from TsNIIChM. Metal pressure against the rolls has been related to drive loading and fall of temp. from pass to pass was followed.

Trends in the development of blooming mills S. V. Makaev (*Stal'*, 1960, (10), 915–919) Increase of degree of reduction per pass with increase in the power of the drives, reduction of the time of passage from soaking pit to mill to 2 min and the installation of tilters at both ends of the mill are recommended.

The scope for work intensification of blooming mills in the light of the performance of auxiliary mechanical equipment I. Kšňa (*Hutn. Listy*, 1960, **15,** (8), 596–597) Times required at various stages along a blooming alley were studied, and are discussed from the point of view of time-matching, such as would be necessary for efficient automation of the entire process. Soaking pit capacity was assumed not to be a limiting factor.—P.F.

The scope for work intensification of blooming mills with regard to the potentialities and limitations of associated electrical equipment V. Pokorný (*Hutn. Listy*, 1960, **15,** (8), 598–602) Adaptations and modifications to the main mill drive, necessitated by reconstructions designed to increase productivity, are discussed in the light of Soviet and Czechoslovak experience and plans.—P.F.

Intensification of production of blooms and billets S. Šlahůnek (*Hutn. Listy*, 1960, **15,** (8), 587–595) Studies of production technology and mill design in the USSR and Czechoslovakia were made, and recent changes in the calibration of rolls in Czechoslovak mills are discussed. Greater reductions per pass were found to increase productivity considerably, without detriment to steel quality. Other measures, such as further perfection of mechanical and electrical equipment, automation, weld repairs of rolls, etc., are considered.—P.F.

Luxembourg's new wire rod mill L. Walter (*Wire Wire Prod.*, 1960, **35,** July, 874–875, and 921–923) A fully continuous wire rod and narrow strip mill in successful operation at Esch in Luxemburg is described with details of layout and some interesting design features and tables of products.—S.H.-S.

Electronic computers and mathematical methods in ferrous metallurgy I. Aczél (*Koh. Lapok*, 1960, **93,** July, 324–328) After discussing the main principles of cybernetics and the feature of electronic computers, the author reports an experiment on cybernetics concerning the programming of the Hungarian barmills. Finally, he reviews various papers published in foreign magazines on cybernetics.

The use of heated rolling to improve the properties of rolled stock from 1Kh18N9T steel G. A. Khasin and V. N. Davidyuk (*Stal'*, 1960, (10), 934) A note from Zlatoust. Rapid cooling of rolled rods from 970–1020°C in 9–17 sec gives the properties required without further heat treatment.

Production of horseshoe iron by rolling periodic sections Lee-Koung-yiao (*Iron & Steel* (*China*), 1959, (4), 114–120; (5), 159–162; from *Sci. Abs. China, Techn. Sci.*, 1959, (3), 224) The plant, roll assembly, and its operation are described.

Republic's bar mill of tomorrow D. E. Weaver and H. E. Berg (*Iron Steel Eng.*, 1960, **37,** June, 91–95) A description of the construction, equipment, and operation of the 11-in bar mill at the Chicago works of Republic Steel

Corp. The mill will roll flats, squares, hexagons, rounds, angles, and heavy coils.

The texture of deformation during the cold rolling of low-alloy dynamo steel K. V. Grigorov and M. Ya. Zakutner (*Fiz. Met. Metallov.*, 1960, **10**, (3), 404–411) In dynamo steel, the appearance of texture takes place roughly proportionately to the full relative deformation. Its increase can be considered a statistical process of the changeover of crystallites from less- to more-stable positions. Its development is much the same as in low-carbon steel (10 refs).

The manufacture and the properties of cold rolled transformer sheets M. Markuszewicz, J. Groyecki, and A. Zawada (*Prace Inst. Hutn.*, 1960, **12**, (3), 131–144) The article is a very comprehensive study, containing much data. Transformer plates made abroad are studied and a detailed comparison between the various plates is drawn up.

Precision rolling of flat products with small diameter work roll M. G. Sendzimir (*Austral. Eng.*, 1960, **52**, July, 47–56) A lecture. Planetary mills are reviewed and illustrated. Non-ferrous mills are included.

How to specify optimum tolerances for sheet G. A. Hoffman (*Mat. Des. Eng.*, 1960, **52**, Aug., 124–126) A graph is given and explained and a table of suitable tolerances is included. the article applies also to Al and Ti. Cost savings by saving weight are estimated.

News about the rolling of thick steel plates A. Chojkowski (*Prz. Techn.*, 1960, **81**, (18), 10) In constructional steels, new plates for bridge-building have been introduced. The requirements of the shipyards are being catered for by work intended to lead to the production of low-alloy steel plates. In the field of temp. and acid-resisting steel, work is going on to introduce laminated sheets, and most of the article is devoted to laminated plates.

The hot wide-strip mill of 'Dunai Vasmü', Hungary Z. Nagy (*Koh. Lapok*, 1960, **93**, July, 302–309) After briefly reviewing the development of foreign hot wide-strip mills, the author discusses the main factors of the operation of continuous and semi-continuous strip mills. Finally, he describes the plan of the new semi-continuous wide-strip mill now under construction in 'Dunai Vasmü', Sztalinváros, Hungary.—P. K.

A million tons of medium strip (*Werk. und Wir*, 1959, **7**, Nov.–Dec., 348–349) This note briefly describes the continuous medium strip mill at the Hohenlimburg works of Hoesch AG which on 19 Oct. 1959 rolled its millionth ton of steel strip. The present monthly production is 35 000 t of strip, 100–560 mm wide.

Working out the parameters for the automatic adjustment of the strip thickness on continuous sheet mills. (Part of the development for the layout of the MMK 1450 hot rolling mill) N. M. Lapotyshkin (*Stal'*, 1960, (10), 935) A note from TsNIIChM. Screwdown has been related to strip thickness and a system of ensuring uniform thickness suitable for automation worked out. Effects of the thermal state of the rolls have been studied.

General Electric X-ray thickness gauge and photoelectric width gauge applied to a hot strip mill S. Oiwa and S. Yamashita (*Nisshin Seiko Giho*, 1959, Dec., 36–43) This article describes the GEC X-ray thickness and width gauge installed in the hot strip mill at the Kure works of the Nisshin Steelworks Ltd in Oct. 1958.

Width gage increases hot strip yield (*Iron Steel Eng.*, 1960, **37**, June, 138) A brief description of the construction and operation of the infra-red non-contacting width gauge on the hot strip mill at the Butler works of Armco Steel Corp.

Non-contacting lineal system programmes tinplate line Designers for Industry Inc. (*Iron Age*, 1960, **185**, May 26, 104–105) Equipment for the recording and computing of data in a hot strip mill is described. Proximity gauges check the strip thickness, plating thickness, and presence of defects. These can be located, and strip length measured by a non-contacting electronic tachometer. A magnetic recording transducer produces a magnetized area on the strip. As it passes a pickup transducer a fixed distance away, this spot is counted and causes another pulse in the first transducer. Thus the length of strip can be measured. This equipment can also be used as an extensometer to measure strip elongation.—D. L. C. P.

What is new in steel rolling mills? I. Frantiu (*Met. si Constr. Masini*, 1960, **12**, (4), 327–330) Mention is made of the new Russian 850/700/500 rolling mill commissioned in 1958 for rolling 60×60; 150×150, and 75×285 mm blanks from 300×300 mm slabs. Capacity 400 t/h driven by 23 000 hp motors; of the Tselikov–Nosal system three-housing planetary mill operating in combination with a continuous steel casting machine; also of blooming-slabbing mills in the Soviet Union with 1250–1300 mm rolls to take 25 t ingots and producing up to 12 t slabs with an output of 4 million yearly. The latest achievements in automation and mechanization of rolling mills are briefly enumerated.

New shapes of rolled sections in Eastern Europe H. P. Witt (*Stahl Eisen*, 1960, **80**, Oct. 27, 1644–1645) New profiles of I-beams are planned in Eastern Europe; this development is quite different from that taking place in the Western part of Europe. The individual differences are enumerated and discussed; three tables of dimensions of the new shapes are included in the report.—T. G.

Roll stainless forms to shape (*Iron Age*, 1960, **185**, June 9, 113) It is explained that roll-formed sections of stainless steel are finding increased use in the building field. Sections can be produced competitively with less durable materials.—D. L. C. P.

Television set up tells I-beam length C. D. Bryant (*Steel*, 1960, **146**, June 20, 114–116) The Video Telegauge system, a non-contact method of measuring the length of I-beams as they are cut at a hot shear is described. A pair of mirrors is mounted on a tower over the shear table. The reflexions of a scale and the end of the beam are brought together on a television screen. The accuracy obtained in tests was $\pm\frac{1}{4}$ in on lengths up to 36 ft. A similar system can be used for several other measuring jobs.—D. L. C. P.

Impact of wire rod rolling mill mechanisation on job requirements S. Descovich and L. Pompilio (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 445–455) The effects of mechanization on work force requirements are analysed for three plants representing three different stages of mechanization—a small hand rolling mill, a semi-automatic rolling mill and a modern continuous mill.

Coiling and transport equipment for wire rod G. Branscheid (*Stahl Eisen*, 1960, **80**, Nov. 10, 1728–1279) This is a review of French practice in wire-rod coiling. One type of coiling equipment handles wire rod of 5–11 mm dia. and the other from 12 to 25 mm. In some cases both types of coilers are combined in one plant. The principles of the coilers are briefly described and details of their use and practice are compiled in tables.—T. G.

Review of the methods for the production of broad and parallel flanged beams: Present-day problems K. Bollmann and G. Kuchenbuch (*Stahl Eisen*, 1960, **80**, Oct. 27, 1501–1507) The various methods for rolling the double T or H beams with parallel flanges where web and flanges are relatively thin are reviewed, and pass design is discussed in the light of experience at the new works at Peine.—T. G.

Possibilities of saving steel in the use of sections K. Rytel (*Neue Hütte.*, 1959, **4**, June, 343–351) Design considerations are discussed for increasing the steel utilization coefficient (the ratio of the load bearing capacity of a particular section to an ideal figure for the same weight), and technical and economic aspects are reviewed.

Rapid change-over of continuous light and medium section mills accomplished L. Wegmann (*Blast Furn. Steel Plant*, 1960, **48**, Oct., 1041–1042, 1044) A note on design developed by Demag to enable modern continuous wire rod, light- and medium-section mills to be changed over in about 5 min.

Batch size in hot rolling K. F. Lindstrand (*Jernkont. Ann.*, 1960, **144**, (8), 573–627) Economic implications of batch size in the hot rolling of steel are examined. The concept of 'small batch loss' is introduced and discussed, with particular reference to Swedish industrial conditions.

Modern methods, machines, update small steel plant F. B. Rackley (*Steel*, 1960, **146**, June 27, 84–86) Modernization of a flat rolled products shop is described.—D. L. C. P.

New stretch reducing mill cuts roll changing time (*Iron Steel Eng.*, 1960, **37**, July, 133–134) A 16-stand mill built by the Aetna-Standard Div. of Blaw–Knox Co. for despatch to TAMSA, Mexico, and designed to reduce 7-in seamless tubing to $1\frac{1}{2}$–5 in, has a housing design with several advantages, including ease of removal of housing unit, simplified roll adjustment, less downtime for size changes and simplified installation.

WELDING AND FLAME-CUTTING

The special features of electroslag welding at low temperatures Yu. A. Sterenbogen, B. F. Lebedev, and A. I. Alekseev (*Avtom Svarka*, 1960, (3), 60–66) A reduction in the initial temp. of the specimen from −20° to −40° in electroslag welding does not affect the mechanical properties of the deposited metal or of the welding joints. The structure of such joints welded at low temp. is practically the same as those welded at room temp. Hence electroslag welding may be used with advantage under Arctic conditions.

Building the Atlas missile A. Ashburn (*Metalov. Prod.*, 1960, **104**, April, 708–711) A short illustrated description of the fabrication and assembly of the stainless steel fuel tank of the American Atlas ballistic missile, which, when welded, is 60 ft long and 10 ft dia., and is held in shape by internal pressure with nitrogen providing rigidity despite variations in thickness of the stainless steel skin in different sections.—S. H.-S.

Friction welding in the Soviet Union E. Bishop (*Weld. Met. Fabr.*, 1960, **28**, Oct., 408–410) The history and principles of the method are briefly outlined and the process is described with practical data and notes on uses and the advantages of the process.

Friction welding: a lesson in economics from Russia A. B. Tesmen (*Met. Prog.*, 1960, **78**, Aug., 101–103) Advantages of friction welding include: low-power consumption, high productivity and adaptability to automatic lines. Characteristics and applications of the process, and Russian equipment are reviewed.

Investigation of welding by friction Kh. A. Tyayar (*Avtom. Svarka*, 1960, (4), 31–35) A method of welding by friction is proposed which may be widely used in repairing machine parts because of the small heat effect on the base metal. The operation can be carried out on lathes with a special device and is very economical, requiring a current of 10–25 volt/amp/mm^2 of cross-section of the rod of depositing metal as against the 100–250 volt/amp/mm^2 needed for electric arc welding.

Fine metal spray joins steel in CO_2 welding method I. D. Holster (*Iron Age*, 1960, **185**, May 26, 106–108) Details of the 'CO_2 spray Arc' method of welding are given. The process is similar to argon-shielded welding and is suitable for similar applications.—D. L. C. P.

All-Russian conference for corrosion-resistant welding joints of stainless steels. 9–10th December 1959 P. T. Dmitriev. **All-Russian conference for the mechanization in plants treating non-ferrous metals, 11–13th February 1960** Yu. A. Yuzvenko (*Avtom. Svarka*, 1960, (5), 89–93) The article contains a brief statement of the papers read, practically confining itself to the titles and authors.

Automated slitting, welding improve industrial grating Dravo Corp. (*Steel*, 1960, **146**, May 16, 100–101) An automated plant for producing welded industrial grating is described. Bars are slit from coiled stock, turned on edge, and passed through a welding machine where crossbars are fused into place.—D. L. C. P.

Welding-soldering of component parts of thin low carbon steel sheet with resistance electrodes M. S. Baranov, Z. A. Krichevskii, and N. I. Kuvyrkin (*Avtom. Svarka*, 1960, (5), 69–77) In view of the good results obtained during trials in Russia with the 'Laycock' apparatus for welding steel sheets up to 1·6 mm thick (of types 08 and 10 steels), a similar apparatus has been constructed in Russia by

the NIIAT with a more powerful transformer, to be used in the motor car industry. A description is given.

Carbon dioxide purging safeguards welding repairs of combustible-gas vessels US Steel Corp. (*Ind. Heat.*, 1960, **27**, May, 997–998) Details are given of the use of a CO_2 purge to prevent explosion during the repair of a BF downcomer.—K.E.J.

Iron electrode strip G. V. Ksendzyk (*Avtom Svarka*, 1960, (5), 78–83) This strip is of varying thickness (0·7–1·0 mm) and structure (from ferritic to pearlitic). A controlled rate of feed and a low Si containing flux of the type AN–28, with high stabilizing properties, ensures steady welding conditions. The rate of melting in the strip differs in the different sections. The most rapid fusion occurs in the zones with the most uniform carbon distribution.

Welding joints of 1Kh20N3G3D2L and 20G3L steels under carbon dioxide N. I. Kakhovskii and A. N. Ponizovtsev (*Avtom. Svarka*, 1960, (4), 22–26) Wire type 10Kh-20N5G3D2 and also the austenitic wire Sv-Kh20N10G6T may be used, both solid and powder electrodes. The machine parts to be welded must first be preheated to 100°, and after welding tempered for 5–6 h at 700±20°.

Electrodes for welding up casting defects in 40KhL and 40GL steels Yu. A. Moshenskii and N. N. Skrynskii (*Avtom. Svarka*, 1960, (2), 72–74) Two types of electrodes, one for each type of steel, have been evolved, as well as suitable coatings. These are tabulated.

Comparison of welding electrode coatings A. Mudde (*Lastechniek*, 1960, **26**, July, 137–141) The connexion and difference between electrode types is demonstrated by some simplified electrode coatings. The FeO content of the slag exerts considerable influence both on the mechanical properties and the behaviour of the slag itself and of the metal during the welding operation.—F.E.H.

Weldability of metals rated by process A. O. Smith Welding Institute (*Mat. Des. Eng.*, 1960, **52**, Aug., 149) Tables of materials and processes with a rating of usefulness are given.

Investigation of the weldability of low alloy steels and of the vibration resistance of welded seams N. M. Lapotyshkin (*Stal'*, 1960, (10), 953) A note from Central Sci. Res. Inst. for Ferrous Met. Types 14KhGS, 14GS, and 15GS were 30–50% more resistant to fatigue than St 3kp low-C types. The specimens had longitudinal weld seams.

Attainability of equilibrium in welding, studied with radioisotopes B. I. Bruk and S. F. Yur'ev (*Svar. Proizv.*, 1956, (3), 1–4) Distribution of sulphur between metal and slag in welding with basic- and acid-coated electrodes was investigated by introducing ^{35}S into the coating and core wire. It was shown that equilibrium in S distribution was not attained in manual welding; the extent to which equilibrium was attained varies with the type of electrode, but only slightly with the welding current.

Investigating the effect of manganese on the redistribution of sulphur between metal and slag when welding low carbon steel L. A. Poznyak and V. V. Podgaetskii (*Avtom. Svarka*, 1960, (4), 5–12) The welding was carried out under type AN–348A flux. With an increase of the Mn content in the metal the ratio (S)/[S] increases, i.e. desulphurization of the metal in the pool takes place. Beginning with a 1·5%Mn content an approximately constant ratio [%Mn]/[%S] is attained in the pool which shows that the reaction $FeS+Mn \rightleftharpoons Fe+MnS$ takes place there. Desulphurization cannot be due to the reaction $[S]+(O^{2-}) \rightleftharpoons (S^{2-})+[O]$ because Mn depresses the chemical activity of S in the pool and is a weak deoxidizer. Radiometric investigations have shown that the transfer of radioactive S from the metal of the pool to the slag is proportional to the Mn concentration in the metal.

The nature of the chemical non-uniformity in the zone of fusion of some pearlitic steels L. S. Livshits, N. A. Grinberg, S. I. Panich, and S. L. Shamonov (*Avtom. Svarka*, 1960, (5), 11–16) When welding joints with different contents of carbide-forming elements in the seam and in the base metal, the nature of the carburizing zone, forming because of the displacement of carbon towards the zone containing the highest concentration of carbide-forming elements, depends on the conditions of the welding operation and on the type of carbides. For a dependable local spectrographic analysis, slight modifications to the type PMT-3 apparatus are suggested.

The kinetics of grain growth in high strength steels during arc welding M. Kh. Shorshorov and B. A. Smirnov (*Avtom. Svarka*, 1960, (5), 17–25) An assessment of grain growth in welding may best be carried out on a rolled specimen or by the IMET–1 apparatus. Both methods show that an increase in the rate of heating, a shortening of the period in which the metal is exposed to austenitizing temp. as well as an increase of carbide-forming elements in the steel, all these limit grain growth in the heat-affected zone. In one-pass welding of steel up to 10 mm thick the degree of homogenization of the austenite is small, in thicknesses from 15 to 25 mm, grains increase considerably in size with a simultaneous increase in the degree of homogenization of the austenite. In electroslag welding of thick steel (100–300 mm) homogenization of the austenite and grain growth are very pronounced.

Concerning crystallization cracks in the heat affected zone S. V. Lashko-Avakyan and N. F. Lashko (*Avtom. Svarka*, 1960, (1), 27–37) The factors determining the tendency to cracking belong to the following groups: chemical composition, structure of the base metal, and nature of the grains which form in the sections of partial fusion; chemical composition of the weld-metal, the nature and kinetics of its solidification and finally the temp. field of the heat-affected zone.

Assessment of tests designed to ascertain the resistance of weld metals to pore formation J. Váňa (*Zváranie*, 1960, **9**, (9), 263–265) [In Czech] Various tests used in submerged arc-welding practice are reviewed. It is concluded that none is entirely reliable, and that the problem requires further investigation.—F.F.

Investigating the operation of roller welding of thin stainless 1Kh19N9T steel V. V. Gorskii and L. T. Babkin (*Avtom. Svarka*, 1960, (1), 38–45) For quality control of the joints it is advisable to make use of the heat expansion of the metal. This, with due regard to the technology of the operation, is a sufficient and essential condition for obtaining good joints. The energy evolved at the contact zone is not a sufficient condition; the current and the voltage drop at the contact zone are not identical with depth of fusion; the total resistance at the contact zone cannot serve as a reliable parameter to control the quality of the joint.

Investigation of the origin of cold cracks in the zone adjoining the welding joints of hardened steels A. M. Makara (*Avtom. Svarka*, 1960, (2), 9–33) The investigation has established that these cracks under special conditions appear as a result of the slow failure of the overheated and hardened metal, by the action of complex stresses originating in the heat-affected zone. The transformation kinetics of the super-cooled austenite in this zone are conditioned not only by the composition of the steel and the thermal cycle of the operation but also by the cycle of the elastic–plastic deformations developing in this zone. These deformations may be explained by the relation between structure and properties of the metals in the weld and in the zone adjoining the welding joint. These stress conditions have been measured. It appears that the cracks begin along the grain boundaries in the coarse grained zones and then slowly develop across the grains also.

Tungsten inclusions in welds made by the argon-arc process on 18/8/1 stainless steel R. W. A. Grocock (*IGR–39 (RD/CA)*, 1959, Feb., pp.10; from *Nucl. Sci. Abs.*, 1959, **13**, Aug. 15, 1815) It is shown that 18/8/1 stainless steel can be welded without W contamination in the argon-arc process.

PROPERTIES AND TESTS

Twinning and fracture of single crystals of 3% silicon iron D. Hull (*Acta Met.*, 1960, **8**, Jan., 11–18) Thin sheet single crystal (001) specimens have been strained in tension at 196°C in the (010) direction. Twins formed, in preference to slip, on four prominent planes $(1\bar{2}1)$, $(\bar{1}21)$, (121), and $(\bar{1}21)$, all equivalent with respect to applied stress. The morphology of the twins is studied and described.—S.H.-S.

Development of high strength stress by working of metastable austenite F. R. Morral (*DMIC Memo*, 39, 1959, Nov., pp.24; from *Nucl. Sci. Abs.*, 1960, **14**, March 15, 582) In hot–cold-worked steels there is a trend of rising strength and falling ductility with increasing carbon content. For aircraft and missile industries, steels containing 0·30 to 0·40%C seem most suitable. It appears that if subcritical deformation of metastable austenite is to become a commercial process development of plant techniques is necessary.

Some observations on localized buckling of centrally notched sheet-steel specimens W. L. Bingham (*NRL rept.* 5412; *PB* 143015, 1959, Dec., pp.8; from *US Res. Rep.*, 1960, **33**, May 13, 545) Bending strains above a transverse slit in variously sized specimens of constant thickness showed buckling only in the widest plate tested (48 in). Values of transverse strains at positions ahead of the slit indicated the presence of a stress-relieving mechanism.—S.H.-S.

Influence of phosphorus on the damping and ageing of iron–nitrogen alloys W. Dickenscheid and J. Brauner (*Arch. Eisenh.*, 1960, **31**, Sept., 531–536) Damping measurements in a torsion pendulum of normal design were made over the temp. range 20–150°C with a frequency of 1 cps, on Fe–N–P alloys containing 0·014–0·167%P, about 0·02%Si, 0·04–0·08% Mn, and 0·015–0·022%S. The damping maximum fell with rising P content, independent of the N content, and the temp. of maximum damping increased. The shape of the damping-temp. curve was noticeably influenced by P content, but not the residual damping. Ageing tests showed that the time taken for the damping maximum to decrease to half its original value increased somewhat at higher P contents (21 refs).

Studies on alloy white cast iron. VII. Compression tests on various white irons I. Fukumoto (*Nippon Kinzoku*, 1959, **23**, Sept., 499–503) Yield stress increased from 30 to 140 kg/mm² with hardness, but was little affected by C content. At constant strain of 1%, compressive stress increased almost linearly with hardness, but at 0·3% strain it varied for the same hardness with S and C content. Two modes of fracture are described, the hardness value separating them being RC 55–60 (10 refs).

Contribution to the study of the deformation of spheroidal graphite cast iron and of mild steel A. Vetiška (*Rev. Mét. Mém. Sci.*, 1960, **57**, Sept., 689–698) It is shown from dynamic and static tests on annealed ferritic specimens (gradual or 'impact' compression) that nodular graphite iron has a lower plasticity than mild steel under severe deformation. Deformation does not alter the elastic properties of the cast iron, which retains a high resistance to shock loading.

Notch toughness of spheroidal graphitic high ductility iron castings V. DePierre and S. Inouye (*NWPW–T–3–59, NAVORD Rep.* 6493, *PB* 161120, 1959, Sept., pp.46) Data from a literature survey of notch toughness and test results were used to show the effect of material variables and external test factors on the notch toughness of spheroidal graphitic cast iron. Material variables are chemical composition, microstructure, and susceptibility to temper-brittleness. External factors include test temp., specimen dimensions, speed of loading, and stress concentration. An equation correlating the nil ductility temp. with material variables and external test factors was obtained from the literature and the test data.

A bend test for toughness D. K. Hannik and G. R. Sippel (*Met. Prog.*, 1960, **78**, Aug., 89–92) In measuring resistance to crack propagation, a simplified bend test was developed which gives results comparable with those obtained by those from elaborate centre-crack tests. The method consists in biaxially stressing to failure a small, unnotched, rectangular speci-

men by bending as a simple beam. The experimental technique and instrumentation are described, and results discussed.

The ductility of nodular cast irons as revealed by the impact test G. N. J. Gilbert (*BCIRA J. Res. Dev.*, 1960, **8**, May, 401–421) Factors affecting the ductility of ferritic nodular irons as revealed in the notched impact test are discussed. It is shown that in order to obtain ductile materials at room temp. capable of withstanding shock loading conditions, the Si, Mn, P, and, to a lesser extent, Ni contents must be controlled within reasonable limits. Annealing can also affect ductility. Pearlitic nodular irons have relatively high transition temp. and are normally used where high tensile strength is essential. In as-cast pearlitic nodular iron this may be low if it has an unusually high transition temp.; the transition temp. is decreased by normalizing which produces homogenization of the structure. The accompanying increase in ductility results in improved tensile properties.

An engineering evaluation of notch sensitivity in high-strength sheet materials. Phase I. Notch testing. Phase II. Hydraulic-bulge testing G. M. Orner and C. E. Hartbower (*WAL–TR–405–1/1*, 1960, March, pp.99; from *Nucl. Sci. Abs.*, 1960, **14**, June 30, 1517) In order to evaluate Ti sheet produced under the Dept. of Defence Titanium Alloy Sheet Rolling Program for notch sensitivity, the feasibility of using an underwater spark discharge technique for bulge testing high-strength sheet materials at impact strain rates was investigated.

Subsize Charpy correlation with standard Charpy C. H. Curll (*WAL–TR–112/95*; *PB* 144923, 1959, Dec., pp.26; from *US Res. Rep.*, 1960, **33**, May 13, 545) Test data tend to verify a previously established non-linear correlation between selected subsizes above the transition range, and further indicate a linear correlation between the energy required to fracture standard-size and subsize V-notch Charpy specimens at the normal acceptance testing temp. of −40°C.—S.H.-S.

Determination of the nil-ductility transition temperature for A212B steel used in the N.S. Savannah pressure vessel W. C. Thurber and J. T. Lamartine (*CF–59–7–143*, 1959, July, pp.26; from *Nucl. Sci. Abs.*, 1960, **14**, Feb. 15, 357) Test specimens taken at two different thickness locations from materials used in the upper closure head of the reactor vessel yielded NDT temp. of 0·20°F which correspond to Charpy-V-notch impact energies of 11–19 ft/lb. Testing of as-received material used in the lower closure head indicated that the NDT temp. was 50°F, which was equivalent to an average Charpy-V-notch impact energy of 12 ft/lb.

A small impact test specimen for irradiation experiments M. Grounes (*NP–8387*, 1959, Sept., pp.16; from *Nucl. Sci. Abs.*, 1960, **14**, June 15, 1368) Difficulties in measuring irradiation-induced susceptibility to brittle fracture are discussed and the advantages of sub-size impact test specimens are indicated. Dimensions of a proposed specimen are listed and preliminary results of Charpy impact testing are included.—S.H.-S.

Crack propagation tests of some high strength sheet steels J. E. Srawley and C. D. Beachem (*NRL–5236*, 1958, Dec., pp.29; from *Nucl. Sci. Abs.*, 1959, **13**, April 30, 727) The results of crack propagation tests using $\frac{1}{4}$ in wide centre cracked tensile specimens are presented for eight different high strength sheet steels. A tentative criterion for evaluation of materials is suggested. Only two steels were found to have a combination of room temp. yield strength in excess of 200 kg/in^2 with fracture appearance transition temp. at or below room temp.

Uniform representation of the results of impact tests on rails with variable profile; consequences for acceptance specifications W. Jänische and W. Wink (*Arch. Eisenh.*, 1960, **31**, Sept., 521–529) Energy loss was determined for a series of rail profiles; it increases approximately with the square of quantity W/e, where W = moment of resistance, e = distance of the outermost wall fibre from the neutral plane. The relationship between residual deflection and work of deformation is no longer a function of the impact sequence. The static bend test is considered theoretically, and relationships are derived by the use of which the various profiles can be considered as similarly stressed. The application of the results of the investigations to the comparison of acceptance conditions in bars with a variable profile is examined.

The effects of welded or sprayed metal deposits on the fatigue strength of shafts K. Wellinger and P. Gimmel (*Eng. Dig.*, 1960, **21**, July, 93–94; from *Werkstattstechnik*, 1960, **50**, May, 269–273) In general fatigue strength is lowered. Recommendations, mainly for cases where welding on spraying build up is inadvisable, are given.

Strain ageing and the fatigue limit of steel J. C. Levy and S. L. Kanitkar (*JISI*, 1961, **197**, April, 296–300) [This issue].

Investigating creep in the weld metal of heat-resistant steels. III. Features of creep in the weld metal of 15KhMA and 20KhMF steels N. L. Kareta (*Avtom. Svarka*, 1960, (2), 62–66) In the ferrite grains of the weld metal and of the metal in the zone adjoining the welds of these two heat-resistant steels, a substructure forms during plastic deformation of the metal while cooling after welding. The substructure raises appreciably the resistance of the metal to heat, supressing the unsteady creep and greatly retarding the established creep. This is explained by the fact that the sub-boundaries impede the formation of 'thin' slip lines preventing the displacement of single dislocations.

The creep properties of an as-cast pearlitic nodular graphite cast iron at 400°C J. A. Towers (*BCIRA J. Res. Dev.*, 1960, **8**, May, 422–424) Creep tests on a pearlitic nodular graphite iron used in an earlier investigation on growth have been carried out at 400°C for periods up to 5000 h at stresses ranging from 8 to 29 t/in^2. The creep properties are shown to be superior to those of flake graphite iron.

Reflections on extrapolation in creep tests G. Krüger (*Neue Hütte*, 1960, **5**, Aug., 481–487) The scatter of experimental results in relation to the permissible load tolerance and experimental temp., and the inhomogeneity of the material are investigated, and a relationship is found between the scatter of results, the permissible scatter of the extrapolation mean, and experimental times. The possibility is shown of using the δ/log t diagram to obtain improved extrapolation results.

The lower critical stress for delayed failure E. A. Steigerwald, F. W. Schaller, and A. R. Troiano (*WADC–TR–59–445*, 1959, Aug., pp.35; from *Nucl. Sci. Abs.*, 1960, **14**, June 30, 1517) On the basis of a distribution law involving hydrogen concentration, applied stress, and temp., the observed changes in the lower critical stress as a function of notch acuity, yield strength, temp., and initial H_2 content were explained for a significant range of these variables.—S.H.-S.

Phenomenological theories of time effects in metals at high temperatures with special reference to primary creep B. C. Hoskin (*AD–205268*, 1957, pp.31; from *Nucl. Sci. Abs.*, 1960, **14**, June 30, 1512) Several of the laws suggested as adequate for describing the mechanical behaviour of a metal at high temp. are reviewed, attention being confined to the case of constant ambient temp. and uniaxial stress systems. Most consideration is given to the question of a law describing the deformation associated with so-called primary creep.

A phenomenological theory for the transient creep of metals at elevated temperatures E. Z. Stowell (*NACA–TN–4396*, 1958, Sept., pp.31; from *Nucl. Sci. Abs.*, 1959, **13**, Aug. 15, 1817) An extension of the theory proposed in *NACA–TN–4000* for the behaviour of metals at elevated temp., in which it is assumed that the metal consists of two phases, each with its own elasticity and viscosity. Non-dimensional creep curves can be constructed from this theory which extend continuously from the transient to the steady-state region. It is shown that the corresponding family of creep curves for any metal can be obtained from the non-dimensional family by use of suitable constants. Good agreement was found with experimental curves, including those of α-iron.

Development of apparatus and methods for measurement of creep at temperatures to 3500°F M. J. Sinnott (*ATI–184781*; *PB* 137450, 1949, Sept., pp.10; from *US Res. Rep.*, 1960, **33**, May 13, 548) A Geiger temp. indicating and recording unit (GETIR) has been successfully coupled to a motor-generator set to control the temp. of an induction-heated furnace. Life tests on a graphite induction furnace with no protection for the graphite show a life of approx. 60 h at a temp. of 3300°F. Various other tests are in progress.

Instability of steel bottoms in waste storage tanks L. E. Brownell (*HW–57274*, 1958, Aug., pp.26; from *Nucl. Sci. Abs.*, 1959, **13**, May 15, 1042) Upward dishing of a waste storage tank is thought to have been caused by vapour pressure between the steel liner and the concrete bottom with a subsequent pressure release allowing the liner to return to the horizontal position. Suggestions for storage tank design are presented.

The how and why of microhardness testing V. E. Lysaght (*Met. Prog.*, 1960, **78**, Aug., 93–97, 122, 124) A report on the characteristics and limitations of the Knoop and diamond pyramid hardness testing methods.

Method for hardenability tests on steels to be hardened inductively K. Kegel (*Härt. Techn. Mitt.*, 1960, **15**, 96–101) Difficulties still to be overcome in the technique of inductive hardening are discussed. Inductive hardening is considered in relation to chemical composition, method of heating, and holding time. Zn apparatus and method for hardenability testing are described.—R.P.

Extension of the Jominy test to the examination of grey castings and of oil-hardenable steels F. Baumgarth (*Härt. Techn. Mitt.*, 1960, **15**, (2), 92–96) Experiments are described showing that commercial grey iron castings can be heat-treated without resorting to special means and the Jominy test can be employed without alteration. The test had to be altered for the examination of the hardenability of oil-hardened steels (15 refs).—R.P.

A study of the hardness of carbides in iron and steel T. Sato, T. Nishizawa, and J. Ishiwara (*Nippon Kinzoku*, 1959, **23**, July, 403–407) For alloy cast irons and tool steels, microhardness figures are given for M_3C, M_4C, $M_{23}C_6$, M_7C_3, and MC, and for Mo_2C and WC (13 refs).—K.E.J.

Age-hardening stainless steels J. Pitaud (*Rev. Nickel*, 1960, **26**, March–April, 31–40) This article describes the various categories of age-hardening stainless steels (austenitic, martensitic, and austeno-ferritic) at present available with special reference to their corrosion-resistance, weldability, and uses.

The contribution of precipitation to strain ageing in low carbon steels D. V. Wilson and B. Russell (*Acta Met.*, 1960, **8**, July, 468–479) Segregates formed beyond the completion of atmosphere locking disperse rapidly on restraining and ageing. Continued ageing gives more stable precipitates, but electron microscopical examination shows that, at ageing temp. of 60°C or less, these are small. Increment in strain hardening capacity due to precipitation is sensitive to the amount of prestrain, and appears to be proportional to $L^{3/2}$.—S.H.-S.

A study of 17–7 PH stainless steel N. L. Carwile and S. J. Rosenberg (*WADC Techn. Rept. 58–653*; *AD–216528*; *PB* 161089, 1959, June, pp.44; from *US Res. Rep.*, 1960, **33**, May 13, 545) A study of mechanical properties and microstructures as affected by heat treatment, with extensive metallographic and X-ray studies to ascertain mechanism of ageing and the precipitation-hardening constituent, the heat tensile and stress-rupture properties at 600 and 800°F being obtained with the TH 950 treatment, is reported.—S.H.-S.

Study on 17–7 PH stainless steel. III. Study on the mechanical properties of 17–7 PH stainless steel containing about 1%Al T. Furukawa and T. Sato (*Nippon Kinzoku*, 1959, **23**, May, 281–284) The M_s point is in the range 150–0°C after quenching from 750–1000°C, and so the steel may be hardened by water-quenching. The best mechanical properties are obtained by ageing after soln. treatment and intermediate quenching. Data are given for the optimum ageing conditions and the max. properties obtained.—K.E.J.

On the changes of thermal residual stresses in low-carbon steel by ageing and repeated stressing S. Taira and Y. Murakami (*Nippon Kinzoku*, 1959, **23**, Oct., 603–607) For 0·16%C steel, data are given for changes in surface residual stresses and hardness caused by ageing at room temp. and at 100°C and by repeated stressing above and below the endurance limit, and for the growth of precipitates. The quench-ageing treatment improves the endurance limit and life, and residual stress helps with this (14 refs).—K.F.J.

Hydrogen embrittlement in terms of modern theory of fracture P. A. Blanchard and A. R. Troiano (*WADC-Techn. Rep.* 59–444; *PB* 161531, 1959, Aug., pp.31; from *US Res. Rep.*, 1960, **33**, June 17, 672) After an attempt to apply Cottrell's theory of brittle fracture to H_2 embrittlement, the influence of the composition of nickel base alloys on their susceptibility to H_2 embrittlement was discussed with the aid of some previous and some new experimental results.—S.H.-S.

The problem of brittle fracture (*Met. Prog.*, 1960, **78**, Aug., 69–72) Progress made with test methods is reviewed briefly, and the centre-notched and edged-notched tensile tests and the bend test are compared.

Bibliography on the effects of hydrogen embrittlement of metals: 1952 to present P. E. Bell (*LAMS*–2283, 1958, Dec., pp.19; from *Nucl. Sci. Abs.*, 1959, **13**, Aug. 31, 1950) Refers mainly to the effects of H_2 on steel and Ti (108 refs).

Embrittlement of steel by hydrogen in pickling and electrolytic plating U. Trägårdh (*Corros. Anticorros.*, 1960, **8**, May, 177–184) The measurement of the brittleness and H_2 content of steel is described. Embrittlement during pickling in different conditions is studied, in acid and alkaline baths, cathodic and anodic, with and without inhibitors. Tests were made for assessing the brittleness of samples of steel after electrolytic plating with various metals: Zn, Cd, Cu, Ag, Ni, Cr, Sn, and tin alloys, with changes in the composition of solution and of addition agents. The return of ductility to steels, by tempering, after long periods of time, is also studied.—S.H.-S.

Theoretical considerations of corrosion and hydrogen embrittlement inhibition (review of contract work at Rutgers University) M. Rosenfeld (*CCL*–88; *PB* 145360, 1960, Jan., pp.25; from *US Res. Rep.*, 1960, **33**, June 17, 670) Hydrogen embrittlement inhibition is proportional to the fraction of anodic area covered by the inhibitor. Inhibition is due to the potential between the anodic and cathodic adsorbed inhibitor and this potential opposes the corrosion potential.—S.H.-S.

Fracture of ductile steel without measurable deformation (brittle fracture and temper brittleness) C. E. Mavrocordatos (*J. S. Afr. IMM*, 1960, **60**, July, 709–740) The factors affecting the phenomena of temper-brittleness and brittle fracture are reviewed, and the simultaneous effect of temp. rate of loading, and ductility are explained in terms of relative changes of yield stress and fracture stress. The relationship is illustrated by a solid three-dimensional model. A direct correlation between low temp. strength and transition temp. is tentatively proposed as offering better means of predicting future behaviour of steels at low temp. A theory which unifies the two phenomena is suggested, and trends in current research on brittle fracture are briefly reviewed.—S.H.-S.

Contribution to the study of embrittlement in special steels: analogies between various types of brittleness observed in ferritic and austenitic steels R. Castro and A. Gueussier (*Rev. Mét.*, 1960, **57**, Aug., 715–724) The experimental work described previously by the authors indicates that embrittlement phenomena are similar in austenitic and ferritic steels, and preliminary heat treatment appears to have a similar effect on both types of structure. The influence of temper-brittleness-determining impurities such as Pb, Sb, and As on the low-temp. brittleness of austenitic steels is examined.

Dialogue between a steelmaker and an engineer on the flaking in steel A. Bartocci (*Fonderia*, 1960, **9**, Aug., 346–348) This discussion centres on the origins of flaking in steel caused by H_2 and its remedy, the effect of advanced testing methods such as ultrasonic testing and the problems of both steelmaker and engineer in this regard.

Study of the intergranular fragility of stainless steels J. Plateau, G. Henry, and C. Crussard (*Rev. Nickel*, 1959, **25**, Nov.–Dec., 139–146) This article discusses the results of a microfractographic examination of the surface of intergranular ruptures which occurred at low temp. The conclusion is that certain ruptures are due to the mechanical effect of the intergranular precipitates. Microfractography analyses this action in the case of 18/8 stainless steel, showing it to be very similar to ductile ruptures.

Influence of niobium on the temper-brittleness of manganese steels I. V. Volobuev and V. V. Gavranek (*Metallov. Obra. Met.*, 1959, (2), 28–33) Mn-containing steels (1·6–2·6%Mn) with up to 1·3%Nb, made in vacuum or atmospheric pressure, were investigated. It was shown that susceptibility to brittle fracture in these steels is sharply reduced by addition of Nb, with an optimum effect at 0·25% Nb; impact strength at sub-zero temp. is increased by the addition of 0·2–0·5%Nb. Metallographic investigations are discussed.

Causes of flake formation in steel P. T. Besedin (*Metallov. Obra. Met.*, 1959, (2), 14–18) It is shown that these causes are: a specified concentration of H_2 for a given steel composition; susceptibility of the austenite to considerable supercooling and to more complete transformation; and the retention of heat stresses during the cooling of relatively massive parts after hot working.

The influence of production technology on the brittleness of 13%Cr turbine steel castings made from arc-furnace melts J. Koutský and F. Kinský (*Hutn. Listy*, 1960, **15**, (7), 524–528) Appreciable improvements in the notch-impact strength of water-turbine castings are shown to result if (a) Fe–Cr is added before the onset of the reduction reaction, all being added at one and the same time, if (b) Al is added to the melt and not to the ladle, with the CaSi added to the ladle, and (c) arc-furnaces are used rather than induction-heated furnaces. Also, the presence of about 1%Ni, while desirable because of delta-ferrite elimination, depresses the Ac_1 and M_s points, necessitating lower tempering temp.—F.F.

Identification and measurement of two types of wear in tools made of high speed steel J. L. Pourny and F. Eugène (*Compt. Rend.*, 1960, **251**, Sept. 26, 1286–1288) Methods of measuring wear by specific abrasion and micrographic analysis are described. In one the particles are only loosely attached to the surface, in the other they are firmly held.

Practical approach to friction coefficients E. Rabinowicz (*Product. Eng.*, 1960, **31**, Sept. 26, 51–53) A general approach suggesting how to relate published data to actual conditions of use.

An experimental study of friction and wear during abrasion of metals B. W. E. Avient, J. Goddard, and H. Wilman (*Proc. Roy. Soc.*, 1960, **258**, Oct. 18, 159–180) Iron and seven other metals were abraded with dry emery paper and the mechanism and effects are examined.

Statistical bifurcation of friction. Technical note No.5 on welding aspect of sliding friction between metallic surfaces F. F. Ling and R. S. Weiner (*AFOSR–TN*–60–207, 1960, Jan., pp.27; from *Nucl. Sci. Abs.*, 1960, **14**, June 30, 1503) An apparatus for measuring adhesion, pure-shear, and friction at so-called extreme pressures is described and test results are discussed.—S.H.-S.

Research programme on high vacuum friction (*AFOSR Report TR*–59–97, *PB* 161116, March, pp.148) A 12 month research programme was devoted to the methodical examination of the friction characteristics of a large number of materials. The principal test condition studied was linear motion between two dry clean unlubricated flat surfaces. The results are reported on ferrous and non-ferrous materials.

Position and prospects of non-destructive and physical materials testing in the metallurgical industry of the German Democratic Republic G. Beckmann (*Neue Hütte*, 1960, **5**, Aug., 474–480) A general review of these factors (35 refs).

Aspects of the Akulov–Bitter patterns in plastically deformed metals E. Gaiginschi, T. Dumitrescu, A. Gutman, M. Zugravel, and A. Birjoianu (*Rev. Roumaine Met.*, 1960, **5**, (1), 41–45) [In English] The aspect of domain patterns in a null magnetic field obtained under tensile plastic deformation of specimens containing 3%Si is characterized by certain bands similar to slip lines, some of which are blank and some filled with colloidal iron particles. It seems probable that plastic deformation results in a transformation of the magnetic into a non-magnetic phase and vice versa.

Radiation damage in steels D. Hull (*Trans. Indian Inst. Met.*, 1960, **13**, June, 151–161) A method is described for relating the increase in yield-stress of En2 steel to the change in notched impact transition temp. Fine grained steels are shown to have lower susceptibility to radiation embrittlement.—A.D.H.

How irradiation affects metals W. L. Fleischmann (*Iron Age*, 1960, **185**, April 28, 106–107) A brief description of the effect of nuclear radiation on the mechanical properties of metals is given. Graphs illustrate how, with carbon and stainless steels, irradiation causes a large increase in yield strength, some increase in tensile strength, less elongation, and a low rate of work hardening, and shifts the impact strength transition temp.—D.L.C.F.

Determination of tensile, compressive, bearing and shear properties of sheet steels at elevated temperatures J. R. Kattus, J. B. Preston, and H. L. Lessley (*WADC–TR*–58–365, 1958, Sept., pp.298; from *Nucl. Sci. Abs.*, 1959, **13**, Feb. 28, 285) The results of tests at various temp. after exposure times of from ½ h to 1000 h at test temp. on various alloy and stainless steels are given.

Spring material at high temperature Hunter Spring Co. (*Prod. Eng.*, 1960, **31**, *Design Digest Issue*, 69; from *Helix*) Relaxation charts for 10 common helical spring materials are given for the range 200–900°F

Supplying cast test bars for high temperature loan alloy study J. Salvaggi (*KA*–875–*M*–14; *AD*–144946; *PB* 137940, 1957, pp.20; from *US Res. Rep.*, 1960, **33**, May 13, 544) Hot strength properties of test bars cast by shell mould process in 17Cr–12Ni–2·5Mo–0·25C stainless steel modified by small additions of Ti, B, and W were investigated and compared favourably with wrought material of similar composition tested previously, being in the same range as those of many superalloys containing appreciable quantities of strategic elements.—S.H.-S.

The effect of Ti on the high temperature properties of austenitic steel R. Nakagawa and Y. Otoguro (*Tetsu to Hagane*, 1960, **46**, May, 566–571) The effects of Ti (0–1·88%) and C (0·06–0·49%) on 18Cr–12Ni steel were studied. Ageing hardness increased with increasing Ti. With Ti > 40, large granular TiC remained on grain boundaries and adversely affected properties. The structure of ppts. is discussed. Tensile strength depended on C in the matrix. The creep rupture strength was highest at Ti = 4C.—K.E.J.

The measurement of the viscosity of melts L. Burnoczky and M. Szabó (*Koh. Lapok*, 1960, **93**, May, 222–225) The authors describe five types of viscosimeter, and their use for the determination of the viscosity of melts.—F.K.

The factors affecting diffusion A. Horváth and M. Achs-Balla (*Koh. Lapok*, 1960, **93**, May, 217–221) The authors discuss the mechanism of diffusion, and the effect of temp. and pressure, as well as of the composition, structure, and thickness of the metal on the diffusion coefficient in the Fick's equation.—F.K.J.

Self-diffusion of iron in nickel and cobalt ferrites R. H. Condit, M. J. Brabers, and C. E. Birchenall (*AFOSR–TN*–58–565; *AD*–158383; *PB* 137435, 1958, July, pp.10; from *US Res. Rep.*, 1960, **33**, May 13, 544) Radioactive iron self-diffusion was measured in nickel and cobalt ferrites in the temp. range 844–1190°C. Rate in Ni was lower by one order, and in Co by two orders of magnitude than in magnetite. Iron diffusion in nickel ferrite appeared to decrease with increasing iron content.

Self-diffusion in the iron–chromium system H. W. Paxton and T. Kunitake (*NP*–8468, 1960, March, pp.31; from *Nucl. Sci. Abs.*, 1960, **14,** June 30, 1516) The self-diffusion coefficient of Cr in various alloys in the Fe–Cr system was measured, and results obtained and others in the literature give a general pattern of behaviour not consistent with present theories of diffusion by a vacancy mechanism. Suggestions are made for clarifying experiments.—S.H.-S.

Observations on diffusion in the iron–chromium system H. W. Paxton, E. J. Pavierb, and T. Kunitake (*PB*–145394, 1959, March, pp.22; from *US Res. Rep.*, 1960, **33,** June 17, 673) Measurements of self-diffusion of Cr using the isotope ^{51}Cr in the Fe–Cr system from 30 to 100%Cr have been made by autoradiographic techniques at 1275°C.—S.H.-S.

Study of the redistribution of carbon in chromium–nickel steels by means of radioisotopes B. I. Bruk and V. V. Nyrkovskaya (*Metallov. Obra. Met.*, 1959, (2), 22–28) Using ^{14}C, certain relations governing the redistribution of C in Cr–Ni stainless steels during tempering were investigated. It is concluded that tempering of 18–8 steel for 6 h at 600°C can result in C-enrichment of the zone round the austenite grain boundaries; a more intensive diffusion of C in this zone occurs on prolonged tempering at this temp. Results obtained by autoradiography confirmed that deceleration of diffusion occurs if the amount of Ti present exceeds four times the C concentration.

Gases in metals G. Ziliani (*Associazione Ital. Metal, Collana techn. AIM*, 1951, No.1, pp.82) This booklet deals in detail with the effects of oxygen, nitrogen, and hydrogen on ferrous metals, devoting a chapter to each. A final chapter describes equipment for the determination of gases in the metal bath, and methods for the rapid cooling determination for metals in the solid state and the reduction with hydrogen, and fusion and vacuum extraction. This chapter also describes the determination of oxygen using micro techniques, determination by ionic bombardment, determination of nitrogen by chemical attack, determination of gases in iron and its alloys and in Ni, Cr, and their alloys.

Aluminium in steel (*Aciers Fins. Spéc.*, 1960, July, 32–35) The effects of Al on steel are discussed from the point of view of deoxidation and as a grain refiner. Al-bearing nitriding steels, precipitation hardening by additions of Al, magnet alloys, and Al as a ferrite-former are summarized.—E.P.

Uses of chromium in ferrous metallurgy (*Aciers Fins Spéc.*, 1960, July, 18–21) The influence of Cr as an alloying element in steels is discussed with special reference to hardenability, wear resistance, resistance to softening on tempering, hot hardness, exodation resistance, and influence on heat treatment techniques.—E.P.

The effects of alloying elements having a marked solubility in nickel–chromium solid solution on the properties of heat-resisting alloys M. V. Pridantsev and G. V. Estulin (*Stal'*, 1960, (10), 936–946).

The effect of alloying elements only slightly soluble in the solid nickel–chromium solution on the properties of heat-resisting nickel alloys M. V. Pridantsev and G. V. Estulin (*Stal'*, 1960, (9), 838–845).

The importance of trace elements for the quality of wire rod B. Matuschka (*Rev. Mét.*, 1960, **57,** Aug., 725–730) Experiments described by the author indicate, from toughness determinations in bend tests, that good quality wire rod should be as low as possible in S, P, Cr, Ni, Mn, and C.

Effects of yttrium on the fabrication and tensile properties of two modified stainless alloys J. A. DeMastry (*BMI*–1420, 1960, Feb., pp.16; from *US Res. Rep.*, 1960, **33,** June 17, 710) No abstract.

Effect of various elements on the properties of 21Cr–4Ni valve steel N. Yamanaka, K. Kusaka, and M. Kitahara (*Tetsu to Hagane*, 1960, **46,** May, 571–577) Data are given for the effects of C, Si, Ni, Mn, and N_2 on hardness, mechanical properties at room and high temp., rupture strength, magnetic permeability, oxidation resistance in air at high temp., corrosion resistance to molten PbO and 40% boiling HNO_3, and change in hardness from nitriding by NH_3 and carbonitriding by $NaCN–BaCl_2$.

Effect of W, Mo and V on the various properties of High-C, High-Cr die steel (SKD 1) S. Koshida and K. Kiyonaga (*Tetsu to Hagane*, 1960, **46,** May, 561–566) Mo and V increased the as-quenched hardness at lower and decreased it at higher temp.; V had the reverse effect. All three elements increased the resistance to temper-softening of quenched specimens, hardenability, and wear resistance. V-containing specimens were relatively insensitive to changes of distortion ratio due to quenching temp. W developed the decomposition of retained austenite in the first stage of tempering, and (Mo+V) depressed this tendency.—K.E.J.

International classification of ferrous alloys A. Wittmoser (*Fonderia*, 1960, **9,** Aug., 355–360) This article summarizes proposals made by Dr A. Wittmoser of Gelsenkirchen for a new classification of ferrous alloys for melting to aid the foundryman, designer, and constructor in the choice of the best materials for the right use of the casting.

New, stronger carbon steel US Steel Corp. (*Chem. Eng.*, 1960, **67,** Sept. 19, 220, 222) An account of A36–60T with comparisons with ASTM A7 and ASTM A373. Savings of 4–6% in the weight of structures can be made.

Development of low alloy steel compositions suitable for high strength steel castings H. R. Larson, R. C. Campbell, and H. W. Lloyd (*WADC Tech. Rep.* 59–63, *PB* 161044, 1959, June, pp.106) Cast high-strength alloy steels were investigated to develop compositions which had 12% elongation, 30% reduction in area, and 15 ft/lb impact strength when heat-treated to 180000 psi tensile strength. Air hardening die type steels were also investigated. Simple plate castings of varying thickness and length were poured to investigate the feeding characteristics of 8740 type nickel alloy. The high purity raw materials had very good properties.

New ultra high strength steels for use at elevated temperatures (*Metallurgia*, 1960, **62,** July, 36) Details of the characteristics of two new steels in the HST series of Samuel Fox & Co. Ltd, a subsidiary of the United Steel Co. Ltd, are given.—S.H.-S.

Ultra-high-strength steels from Samuel Fox (*Brit. Eng. Transport*, 1960, **43,** Nov., 115) An account of the properties of HST 100, 120, and 140 with tensile strength of 100–140 t/in^2.

Deep-drawing sheet from stabilised non-ageing steel D. Tlustá and J. Skála (*Hutn. Listy*, 1960, **15,** (8), 602–609) It is shown that additions of 0·05%V render rimming carbon steel non-ageing. The V has no detrimental effects on the steels; drawability is improved, grain size is reduced, and segregation in ingots is also less than in non-stabilized steels.—P.F.

Standard designations of alloys for aircraft and missiles. Trade names, aeronautical and military specifications and producers of stainless steels, alloy steels, and super alloys J. J. Vagi (*DMIC–Memo*–42, 1960, Jan., pp.60; from *Nucl. Sci. Abs.*, 1960, **14,** June 30, 1503–1504) Tables are presented, with a list of selected high-strength and heat- and corrosion-resistant alloys.—S.H.-S.

Classification of Soviet gas-turbine steels. Review of Soviet Literature, 1954–1959 (*NP*–8505, 1959, Oct., pp.18; from *Nucl. Sci. Abs.*, 1960, **14,** June 30, 1505) A description of Soviet high-temp. steels, especially those used in the manufacture of gas turbines, with their characteristics and a code for their classification. (Information obtained from a review of Soviet literature, 1954–1959.)—S.H.-S.

Developments in and relating to alloy steels E. W. Colbeck and T. H. Middleham (*BP* 826466, 1960, Jan. 6; from *Nucl. Sci. Abs.*, 1960, **14,** April 5, 842) High-B steels are described in which loss of workability is compensated by Al additions. The steels have permissible radiation characteristics and are forgeable by light hammering.

Microstructures and notes on steels made to BS 3100:1957:1617 Grade A J. Turton and B. H. C. Waters (*Brit. Found.*, 1960, **53,** July, 329–333) The mechanical properties of as-cast and heat-treated steels containing 0·10–0·13%C and their magnetic properties are given.—A.D.H.

A new type of high strength alloy steel (*Technico-Scientific Work*, 1958, (3), 8; from *Sci. Abs. China, Techn. Sci.*, 1959, (1), 52) Properties of a new type of low-alloy steel (No.80) containing no Ni, and of another type of constructional steel (No.200) are reported.

9% nickel alloy steel can reduce your material costs (*Austr. Mach. Prod. Eng.*, 1960, **13,** April, 42–43) A special report on new material problems involved in low-temp. storage and transportation of cold liquefied gases, and in processing equipment free from brittleness and fracture characteristics.

Special steels with tensile strength of 250 kg/mm² and above M. Maroy (*Mines Met.*, 1960, April, 205) A description is given of the 'ausforming' technique developed mainly by the Ford Laboratories, in which Ni–Cr–Mo steel (~0·4%C, 1·65–2%Ni, 0·7–0·9%Cr, 0·3%Mo) is severely reduced by rolling to sheet at 420–560°C, followed by a suitable heat treatment. The structures produced are discussed. High tensile strength and good ductility are obtained.

Developments in special steels Sir Frederick Pickworth (*Financial Times*, 1959, Aug. 10, vi) Demands on modern materials are discussed in general terms.

Tool steelmakers shoot for new markets (*Steel*, 1960, **146,** April 8, 127–142) Separate articles deal with the production, selection, and uses of tool steels, and the results of a survey into the habits of buyers is reported. One conclusion is that there is increasing scope for applications other than tools.—D.L.C.P.

New tool steel selector programme aids warehousers and users M. M. Fenner jun. (*Steel*, 1960, **146,** April 25, 118–122) A system to help users to select and order tool steel is described. A limited number of grades has been selected by the firm, which caters for 96% of the required applications; ample stocks of these grades are held. A 'Steelector' card is published which clearly compares the properties of these grades.—D.L.C.P.

U.S. Steel dedicates electromechanical laboratory (*Iron Steel Eng.*, 1960, **37,** June, 135–136) An outline of the programmes planned for the laboratories opened officially on 18 May 1960 at the Research Centre of US Steel Corporation at Monroeville, Pennsylvania.

National Engineering Laboratory. Research on materials and their fabrication (*Metallurgia*, 1960, **62,** July, 29–35) The work of the laboratory is broadly reviewed under the two main headings of 'The Forming of Materials' and 'Properties of Materials'. A list of contemplated functions of the Creep Information Centre is added.—S.H.-S.

Materials testing department (*Inst. Sper. Met. Leggeri, Ann. Rep.*, 1958, 51–56) The internal research programmes carried out or in progress are briefly described. They include fatigue resistance of light alloys under plastic working, influence of subnormal temp. on mechanical characteristics of light alloys, standardization of tests of welded plates, and standardization of traction tests on sheets. Some work on ferrous metals is included.

METALLOGRAPHY

The determination of unstable highly dispersed carbides isolated from steels L. Brháček and A. Golonka (*Hutn. Listy*, 1960, **15,** (7), 575–586) The design and performance of an electrolytic apparatus are described, and the factors affecting its performance are discussed on the basis of extensive experimental results.

Nucleation and particle growth in precipitation in solid solutions O. Krisement (*Arch. Eisenh.*, 1960, **31,** Sept., 537–548) In the decomposition of supersaturated solid solutions the nucleation of the new phases can be treated according to two theories, due to Becker-Döring and Borelius. The diffusion-controlled growth of single-phase particles is investigated in detail, together with the growth of lamellar systems (33 refs).

A new optical method for the determination of non-metallic inclusions in steel T. Ernst and G. König (**Verein deutscher Emailfach. Mitt.*,

1959, **7**, Dec., 93–96) Electrolytically separated inclusions are examined in an immersion liquid for refractive index, colour, and size.

Carbide formation during the isothermal decomposition of alloyed austenite in hypereutectoid steels I. S. Anitov (*Metallov. Obra. Met.*, 1959, (2), 19–22) An investigation is made of the isolation of the carbide phase during the decomposition of the austenite in steels containing about 0·9%C, and either Ni, Mn, Cr, W, Mo, or V. The kinetic curves in each case are reproduced, and the results discussed.

Investigations on nonmetallic inclusions in transformer sheet and on their influence on hysteresis losses F. Pawlek and D. Seeger (*Arch. Eisenh.*, 1960, **31**, Aug., 485–490) The inclusions were isolated electrolytically from sheet with 3 to 4·5%Si. The improvement found in the magnetic properties on annealing in a vacuum was attributed to the avoidance of nitride precipitation. It was found that the sheet with the highest coercive field strength and hysteresis losses contained Al nitride. Of the remaining nitrides, those of Si and Ti, the influence of the former was less than that of Al, and that of Al could not be accurately determined because of the small amounts present (14 refs).

Evidence for successive microheterogeneity states in the precipitation of carbides in Fe–Ni–Cr austenite J. Philibert, C. Crussard, X. Wache, and M. Gerber (*Compt. Rend.*, 1960, **251**, Sept. 26, 1289–1291) The heterogeneity of the solid austenitic solution of 36%Ni and 11%Cr was revealed by P. Chevenard using the thermomagnetic method. Some microboring analyses by Castaing show that this heterogeneity is revealed by the presence of dechromed (−3 to −4%) and excessively nickelled (+5 to +6%) halos round the precipitated carbides.

New carbide produced in the transformation of carbon–silicon steels J. Pomey, J. Deliry, M. Wintenberger, R. Lafont, P. Lesage, and A. Diament (*Compt. Rend.*, 1960, **251**, Oct. 10, 1507–1508) Si–C steels subjected to bainitic transformation between 350° and 450° produce a new carbide with a Curie point approaching 370°. The isothermic decomposition of the austenite around 400° takes place in two stages; in the first, ferrite increases while the austenite is enriched in carbon; in the second the austenite breaks down into ferrite and this new carbide.

The decomposition of the crushed carbides and nitrides after cold deformation and the ageing of high carbon steel O. Bakalikova and A. Mašin (*Studií si Cercetari Met.*, 1960, **5**, (2), 151–157) Steels with high carbon content are normally considered non-ageing because the carbon and nitrogen atoms, the segregation of which produces ageing, are closely bound in these steels as carbides and nitrides. But high-carbon steels (0·6%C) after cold deformation do age; variations in their electrical resistance and observation under the electron microscope have shown that a decay occurs of the carbide and nitride particles when crushed during cold deformation so that the carbon and nitrogen atoms recover their freedom to diffuse freely through the crystal lattice.

The isolation of oxide inclusions and their chemical analysis J. Mika (*Koh. Lapok*, 1960, **93**, June, 250–255; July, 310–314) After comparing various methods for the isolation of oxide inclusions in steels, the author suggests the use of electrolysis and subsequent chlorination. The latter may be carried out in a stream of A in place of a vacuum; and the chlorides obtained can be separated from the oxides simply by dissolution, instead of sublimation. Finally, a photometric method has been described and proposed for the analysis of the isolated oxides.—P.K.

Preparation of single crystals of nickel and Ni–Fe alloy A. Modrzejewski (*NP*–8162, 1959, Sept., pp.8; from *Nucl. Sci. Abs.*, 1960, **14**, March 15, 550) An apparatus for preparation of single crystals of Ni and Ni–Fe is described. The Bridgeman method is used and conditions for growing the crystals are given.

Austenite grain size in 18–8 steel alloyed with small amounts of boron S. M. Vinarov (*Izvest. VUZ Chern. Met.*, 1958, (8), 163–165) The effect of boron is discussed and cases where grain growth is reduced are quoted. Trials with 18–8 steel were carried out and it was confirmed that B lowers grain boundary surface energy and arrests grain growth to a greater or lesser extent.

Recrystallization texture of cold-rolled 50-iron 50-nickel alloy H. Abe and F. Seki (*Nippon Kinzoku*, 1958, **23**, June, 343–347) X-Ray diffraction results are given. Before primary recrystallization, sharpening of the cold-rolling texture is observed, probably caused by polygonization. The nuclei of cube-oriented recrystallized grains are formed by the Burgers–Cahn mechanism in the local curvature of the cube-oriented deformed matrix (31 refs).—K.E.J.

The causes of secondary banded structures and their influence on steels U. Wyss (*Härt. Techn. Mitt.*, 1960, **15**, 14–19) According to previous work, the banded ferrite-pearlite structure is due to concentration differences of residual and of alloying elements. Phosphorus enrichment favours ferrite formation in plain steels whereas in alloy steels ferrite formation will be initiated in dendrites depleted of alloying elements. The influence of time, temp., degree of deformation, and austenitic grain size is described.—B.P.

On the fine bands appearing in the electron micrograph of the martensite of Kovar Z. Nishiyama, K. Shimizu, and R. Kawanaka (*Nippon Kinzoku*, 1959, **23**, May, 311–314) Lamellae (spacing 150–300 Å) are revealed by light etching. Their form and density resemble those in Fe–Ni alloys. They are parallel ridges, different from normal deformation slips, and are denser and more uniform over the martensite plate than the latter. Their appearance indicates that slip with fine spacing occurs during transformation.—K.E.J.

Investigating the eutectic transformation of iron K. P. Bunin, I. P. Gorlova, and S. A. Fedorova (*Lit. Proizv.*, 1960, (7), 18–19) Three series of tests are described on essentially the same iron but with varying Si contents. The original structure consisted of coarse dendrites of austenite and colonies of graphitic austenite eutectic. The investigations covered the kinetics of the eutectic transformation of lamellar graphite iron and also the kinetics of the second stage of graphitization at constant annealing temp. and conditions.

On cementites substituted simultaneously with chromium, molybdenum and manganese in new alloy low-carbon steels L. Bäcker, R. Bigot and E. Herzog (*Compt. Rend.*, 1960, **251**, Oct. 3, 1388–1390) An attempt has been made to find out the behaviour of cementites substituted in low-alloy steels after various methods of heat treatment in oder to establish the solubility limit of Cr, Mo, and Mn in this carbide. The carbides were isolated by the electrolytic separation process and studied by chemical analysis and X-ray diffraction. The results are given in detail.

On the Ar^{11} transformation of high-C and high-Cr steel using 'direct-vision equipment for the magnetization curve' T. Matsukura, A. Nagai, and E. Matsumoto (*Nippon Kinzoku*, 1959, **23**, Aug., 473–477) Visual measurements were made on a cathode-ray oscilloscope. During the transformation, coercive force increases greatly at the start and soon becomes constant; this is different from the increases of saturation and residual induction. This behaviour arises from the fineness of martensite particles. An equation is given which connects residual induction and coercive force during transformation by quenching (10 refs).

Isothermal decomposition of austenite in ARC 3 steel B. Rotenstein and I. Dragan (*Rev. Roumaine Met.*, 1960, **5**, (1), 25–39) [In Russian] The kinetics of transformation in the pearlitic zone show the usual isothermal reactions at these temp., but in the intermediate zone there are two distinct transformation intervals. The upper region shows the formation of upper bainite and pearlite (the kinetic curves between 450° and 350°C have two branches). The lower region shows the formation of lower bainite. The appearance of the critical point at about 340°C points to an increased resistance of the superheated austenite to transformation.

The effects of stress in cooling on the stability of austenite. I. The effects of the stress induced by preventing the thermal contraction on the amount of retained austenite I. Hagiwara, S. Kanazawa, and U. Kumada (*Nippon Kinzoku*, 1959, **23**, May, 299–302) Detailed data show that stress has no effect on the thermal stabilization of austenite in high-C alloy steels. In medium- and low-C alloys teels, stabilization by preventing thermal contraction was not observed, and in the low-C steel the amount of γ_R was decreased (in contrast with high-C alloy steel) (11 refs).—J.E.J.

On the martensite transformations Z. Nishiyama (*Trans. Indian Inst. Met.*, 1960, **13**, June, 133–139, discussion, 139–140) Characteristics of martensitic transformations are reviewed and the influence of substructures on the theory is noted (19 refs).—A.D.H.

The structure of the phosphide eutectic in iron Ya. N. Malinochka and N. G. Osada (*Lit. Proizv.*, 1960, (7), 21–24) This problem was investigated from the point of view of the structure of the phosphide eutectic as well as regarding the effect of heating on this structure. It has been established that envelopes round the phosphoric ferrites in the matrix form only round those islands in which, in the original structure, little pearlite was present. Upon austenitizing this matrix, low-carbon austenite appears within which phosphorus may freely diffuse, so that carbon is forced out and the matrix again becomes ferritic. A prolonged holding at high temp. results in the austenitizing of the phosphoric ferrite.

The solid solubility and constitution of yttrium in iron–20 to 40 w/o chromium alloys M. S. Farkas and A. A. Bauer (*BMI*–1386, 1959, Oct., pp.22; from *Nucl. Sci. Abs.*, 1960, **14**, Feb. 15, 357) The solid solubility was determined by metallographic techniques and found to be extremely small, the maximum at 1320°C being about 0·12 wt.-%Yt. Study of iron-rich alloys of the Fe–Yt system shows that the compound $YtFe_3$ exists. A eutectic occurs between iron and $YtFe_3$ at 1257°C.

Iron–aluminium alloy systems. Part 13. Development of creep resisting compositions R. H. Richman (*WADC–TR–57–298* (Part 13), 1959, April, pp.22; from *Nucl. Sci. Abs.*, 1959, **13**, Aug. 31, 1952) The effects of 1–4%Mo and ½–1%Ti on the mechanical and metallurgical properties of Fe–7%Al are reported. Only alloys with 3–4%Mo and ½–1%Ti possessed promising elevated temp. properties. It was concluded that Mo and Ti served mainly as solid solution strengtheners.

The solubility of silicon nitride in ferrite R. Rawlings and P. M. Robinson (*JISI*, 1961, **197**, April, 306–308) [This issue].

Determination of the Zr corner of the Zr–Fe–Sn system at 0·1 and 0·2% oxygen levels C. R. Lillie (*AECU*—4068, 1959, Jan., pp.58; from *Nucl. Sci. Abs.*, 1960, **13**, June 30, 1500) It is found that oxygen stabilizes not only the α-phase in Zr but also two intermetallic compounds. $ZrFe_2$ and the θ-phase. The θ-phase which chemically appears to be Zr_2Sn with about 8%Fe replacing Zr is shown to be stable at 1010° and probably also at 1100°C.

Investigation of the TiFe–V composition diagram Pi Ch'ing-hua and I. I. Kornilov (*Zhur. neorg. khim.*, 1960, **5**, (4), 902–907) This diagram of the quasi-binary system has been studied for the first time by means of thermal and X-ray analysis and by hardness measurements of the alloys. The results have been used for the construction of the diagram. A ternary metallic compound (TiFe)V has been revealed. It is formed by peritectic reactions and occupies a small volume in the γ-solid solution. (TiFe)V has a hexagonal lattice with parameters $a = 4{\cdot}88$ Å; $c = 7{\cdot}96$ Å, and $c/a = 1{\cdot}63$. It shows great hardness ~800 Hv.

The bismuth–iron–sulphur ternary system (on the theory of the precipitation melting of the bismuth) G. G. Urazov, K. A. Bol'shakov, P. I. Fedorov, and I. I. Vasilevskaya (*Zhur. neorg. Khim.*, 1960, **5**, (3), 630–636) The Bi–S system was investigated by means of thermal and microstructural analysis, as were also five zones of the Bi–Fe–S ternary system and the boundaries of the stratification zones. The data obtained have been used to construct the fusibility diagram of the zones in which the basic reaction of the precipitation melting of

the bismuth take place. The stable section, Bi–Fe sulphides, is divided into two zones which consist of elementary ternary systems. In both these zones the crystallization of all alloys ends with the formation of the ternary eutectic corresponding practically to pure Bi. The results demonstrate the practically irreversible character of this reaction.

Compatibility of U-10 Mo with 304 stainless steel at 1000°F R. S. Neymark (*NAA–SR–Nemo*–4943, 1960, Feb., pp.7; from *Nucl. Sci. Abs.*, 1960, **14,** June 15, 1362) A study was made to evaluate the compatibility of stainless steel clad U-10 wt-%Mo fuel with Na and NaK bonds at 1000°F. No evidence of interalloying between the U-10 wt-%Mo and the Type 304 stainless steel cladding was found. Exposures were made with Na and NaK bonds for 744 and 2184 h.—S.H.-S.

Studies of zirconium–iron–tin alloys L. E. Tanner and C. R. Simcoe (*ARF*–2068–6, 1959, April, pp.46; from *Nucl. Sci. Abs.*, 1959, **13,** Aug. 15, 1814) An investigation of the intermetallic compounds $ZrFe_3$ and Zr_4Sn at 500 and 1100°C showed that Zr_4Sn and θ are separate phases not in equilibrium with one another; $ZrFe_3$ was established at its stoichiometric composition of 55 wt-%Fe, with apparently negligible solubility for Sn.

CORROSION

Stress corrosion J. Dirian (*CEA–BIB–2*, 1959, pp.52; from *Nucl. Sci. Abs.*, 1960, **14,** July 15, 1623) An abstract bibliography with 240 refs. dealing with stress corrosion from both a technical and practical point of view, with regard to steels, light alloys, and other metals and alloys.—S.H.-S.

3e colloque de métallurgie sur la corrosion (sèche et aqueuse). Saclay, June–July 1959 (*Report of Colloq., N. Holland Publ. Co.*), 1960, pp.244; from *Nucl. Sci. Abs.*, 1960, **14,** July 15, 1625) Twenty papers are included, with separate abstracts for each.—S.H.-S.

Basic researches in metal corrosion G. Bianchi (*AFOSR–TR–59–76*, 1959, April, pp.10; from *Nucl. Sci. Abs.*, 1960, **14,** June 15, 1361) The electrochemical processes of O_2 and H_2O_2 on Pt graphite, and Au electrodes have been studied to get a knowledge of the mechanism of oxygen corrosion. The results are described.—S.H.-S.

Diffusion mechanisms and gaseous corrosion W. J. Moore (*3rd Colloque Corrosion, Metall, Saclay*, 1959, June–July, 19–22; also *Nucl. Sci. Abs.*, 1960, **14,** July 15, 1625) The various types of defect mechanism that may be applicable in diffusion in solid oxides and sulphides at high temp. are described. The relation of tracer diffusion coefficients to parabolic rate constants is restated in the formulation of Wagner. It is shown that this implies a linear proportionality between rate and driving force for the reaction and the conditions necessary for this to apply are specified.

The intercrystalline cracking of metals J. N. Greenwood (*Trans. Indian Inst. Met.*, 1960, **13,** June, 163–175) Mechanism is considered. The tests were made on non-ferrous materials.

Metals for sea water service F. W. Fink (*Ind. Eng. Chem.*, 1960, **52,** Sept., 58A–58A) A review of factors in sea-water corrosion and of the performance of iron and steel and non-ferrous metals.

Decomposition of solid ferrous hydroxide in high-temperature water A. S. Kesten and L. S. Lasher (*WAPD–BT–16*, pp.102–111; from *Nucl. Sci. Abs.*, 1960, **14,** May 31, 1192) Conversion of freshly released, ferrous-alloy corrosion products to particulate magnetite, its nature and rates, effects on rate of primary system contamination, together with its results showing that pure solid FeOH decomposes rapidly to form metallic iron and magnetite, primarily the latter, are described.

Metallurgy division semi-annual progress report for period ending October 10, 1959 (*ORNL*–2217 (Del.), 1959, Nov., pp.231; from *Nucl. Sci. Abs.*, 1960, **14,** July 15, 1622) Progress in corrosion studies in numerous metals and alloys, and developments in high-temp. metals and ceramics, metallographic techniques, ceramic materials, and Zr alloys are reported.—S.H.-S.

Literature survey on aqueous corrosion of stainless steels (with a special reference to corrosion in boiling and pressurized high-purity water) (*LS*–48, 1959, Aug., pp.10; from *Nucl. Sci. Abs.*, 1960, **14,** July 15, 1624) A bibliography (83 refs).—S.H.-S.

Literature survey on the corrosion of stainless steels in nitric acid (the effect of temperature, concentration, and the presence of several ions in the solutions) (*LS*–46, 1959, Aug., pp.10; from *Nucl. Sci. Abs.*, 1960, **14,** July 15, 1624) A bibliography (84 refs).—S.H.-S.

New perspectives in the stress corrosion problem H. H. Uhlig (*NP*–7601, 1958, pp.25; from *Nucl. Sci. Abs.*, 1959, **13,** Aug. 31, 1951) The mechanism of stress corrosion cracking is discussed, and the resemblance of H_2 cracking of steels and cracking of Mg_2Sn crystals without stress to stress corrosion-cracking is pointed out. It is suggested that selective adsorption of ions lowers the surface energy, co-operating with electrochemical action.

Caustic-induced stress cracking of stainless steel F. W. Pement (*WAPD–BT*–16, pp.112–133 (no date); from *Nucl. Sci. Abs.*, 1960, **14,** May, 1238) Results of tests conducted to determine what combinations of temp. and LiOH concentration cause cracking of austenitic stainless steel samples containing high residual stresses are described. A factor of over 1000 would be required in a process of concentration before harmful effects are caused by the presence of LiOH in primary coolant at pH 10—a very unlikely possibility for pressurized water reactors.—S.H.-S.

On the intercrystalline corrosion of 24/10 austenitic Cr/Ni steels V. Čihal, P. Gröbner, J. Jezék, and R. Pospíšil (*Hutn. Listy*, 1960, **15,** (7), 518–524) An electron micrographic study of the corrosion process showed that as a result of intergranular precipitation of Cr carbides, the Cr content in the grain boundary region may drop below the passivation level, and thus facilitate corrosion. The results confirm recent observations made by means of the electron-probe micro-analyser.—P.F.

Corrosion of an iron–chromium–aluminium alloy by synthetic fuel oil ash J. P. Kelly (*AD–147472; PB* 144918, 1957, Aug., pp.15; from *US Res. Rep.*, 1960, **33,** May 13, 549) In tests at 1700° for max. of 20 h on a Fe–Cr–Al alloy (25%Cr:4·7%Al) in synthetic fuel oil ash corrodants of high V and Na contents it had better resistance than type 310 alloy.—S.H.-S.

Corrosion and fires in marine boiler air preheaters, with particular reference to the Ljungstrom rotary regenerative air heater A. Bell (*Trans. Inst. Marine Eng.*, 1960, **72,** Aug., 309–324) Formation of SO_3 is reviewed and a report on observations of corrosion in 24 ship installations is given. Methods of prevention are discussed.

Corrosion resistance of welding joints of 1Kh18N9T steel when used in apparatus for treatment of sulphur-containing oils from the eastern deposits S. V. Yunger, B. I. Medovar, and N. A. Langer (*Avtom. Svarka*, 1960, (3), 19–30) Steel used in the sulphur oil industry is exposed to chemical actions of different intensities depending on the composition of the different fractions and temp. In gaseous media, i.e. at temp. between 400°–550° when no electrolyte can form, no conditions exist for intercrystalline corrosion, but at lower temp. (30°–150°) when condensation takes place, intercrystalline corrosion occurs. Austenitic–ferritic welding joints made with EI 606 wire or with GL–2 electrodes (alloyed with V) are superior in resistance under these conditions to other wires.

Influences of local temperature increases on the fretting corrosion of mild steel R. B. Waterhouse (*JISI*, 1961, **197,** April, 308–313) [This issue].

Corrosion failure of butt welded tube of 17% chromium stainless steel B. I. Medovar and L. N. Yagupol'skaya (*Avtom. Svarka*, 1960, (3), 70–74) A few suggestions based on extensive investigations are proposed among which is not to use tubes of Kh17 steel in acid-resistant weldments. These should be replaced by the stabilized type Kh17T as Ti slightly inhibits grain growth. If however non-stabilized steel has to be used, the welded joints must be locally heat-treated.

Corrosion of carbon steel in waste solutions containing mercury P. N. Kranzlein (*DP*–416, 1959, Nov., pp.12; from *US Res. Rep.*, 1960, **33,** June 17, 711) No abstract.—S.H.-S.

Precipitates, fragility and intergranular corrosion of 18–8 stainless steel J. Plateau, G. Henry, and C. Crussard (*Proc. 3rd Colloq. Mét. Corros., Saclay*, 1959, June–July, 185–199; from *Nucl. Sci. Abs.*, 1960, **14,** July 15, 1627) Morphology of intergranular and intercrystalline chromium carbides formed during annealing of 18–8 stainless steels, influence of the duration and temp. of the annealing process, influence of the carbon content, and the possibility of an epitaxic or coherent growth were studied.—S.H.-S.

Corrosion of stainless steel in Thorex process solutions P. M. Krankzlein (*DP*–429, 1959, Dec., pp.15; from *Nucl. Sci. Abs.*, 1960, **14,** 1237; also *US Res. Rep.*, 1960, **33,** June 17, 711) The effects of the solutions met with in the Thorex and Purex processes are compared, corrosion of 304L and 309SCb stainless steels are similar, except in the dissolving and waste evaporation steps in the Thorex process.

Present knowledge of the corrosion of steels by hydrogen sulphide E. Herzog (*3rd Colloque Metall. Corrosion, (1959, June–July)*, 1960, 217–239; also *Nucl. Sci. Abs.*, 1960, **14,** July 15, 1627) [In French] Corrosion by H_2S in aqueous media is electrochemical. Cells are formed between the sulphides and the iron. H_2S accelerates the diffusion of protons in the steel and increases the potential of their surface concentration. It encourages attack on the joints between the grains. The knowledge of internal stresses caused by the diffusion of protons enables rupture tendencies to be interpreted; a high potential causes rapid rupture and a low potential does not cause ruptures at all.

Oxidation of iron–chromium alloys D. Lai, R. J. Borg, M. J. Brabers, J. D. Mackenzie, and C. E. Birchenall (*AFOSR–TN–60–387*, 1960, Feb., pp.37; from *Nucl. Sci. Abs.*, 1960, **14,** July 15, 1623) The rates of oxidation are measured and the nature of the products investigated by metallography, X-ray diffraction, and chemical analysis. A mechanism for scale embrittlement by Cr is proposed, and the ways in which Cr might contribute to a reduced rate of oxidation of iron are discussed.

The morphology of oxidation films. I. Precipitation in oxides. II. Micrographic structure of films J. Paidassi (*3rd Colloque Metall. Corrosion, Saclay (1959, June–July)*, 1960, 71–72, 72–81) [In French] After studying the oxidation of several pure polyvalent metals (Fe, Cu, Mn, Ni, U) and their oxides at high temp. and atmospheric pressure the author suggests how to modify the usual representation of the oxide film to bring it nearer to reality. In this first part the author examines the real micrographic structure of the oxidation film and gives examples of precipitation in the oxides during cooling of the oxidized sample. **Part 2. III. Study of interfaces. IV. Film growth induced by substrate** (84–89) (89–95) In the second part the writer studies the special features of different interfaces of the real scale and gives examples of its growth induced by the metallic substratum. **Part 3. V. Nucleation of oxides and growth in the film (97–104). VI. Plastic deformation of the oxidized samples (104–110)** (71–72, 72–81) Examples are given of the appearance of an oxide in the form of isolated crystals and the plastic deformation of the oxidized samples is discussed.

Recent development of ideas regarding the oxidation of metals J. Bénard (*3rd Colloque Mét. Corrosion, (1959, June–July)*, 1960, 1–8) [In French] The first part recalls various attempts to establish a general theory of the oxidation of metals by Pilling–Bedworth, Cabrera–Mott, and Wagner. In the second part it is shown that the basic process of oxidation reactions is often masked by secondary phenomena whose role often appears decisive in the development of the reaction. Finally the results are described of investigations of nucleation, surface diffusion, and chemisorption.

The oxidation of metals and alloys (*AFOSR–TR–59–43, AD* 214525; pp.39; from *Nucl. Sci. Abs.*, 1959, **13,** Aug. 15, 1813) Results of research on the absorption of non-collimated radiation in measuring diffusion by tracer

techniques are presented, together with results of investigations of oxides, and the effects of pores and cracks on the kinetics of oxidation, and the role of defects in oxide and sulphide crystals on conductivity, diffusion, and grain growth. Variation of self-diffusivity in the Curie point of α-iron was determined at 980–1167°K using ^{55}Fe. Data are also given on Fe–Ni–O equilibria, and on the metal–sulphide equilibria for some non-ferrous systems.

Selection of alloys which resist corrosion at high temperature J. Génilloud (*3rd Colloque Mét. Corrosion, (1959, June–July)*, 1960, 37–51) [In French] Tests to compare resistance to oxidation were carried out in the temp. range 700–1100°C and lasted 2000 h. This article describes the 30 types of alloys and the experimental method used, and the results obtained.

Oxidation of ordinary steel or alloys heated in carbon dioxide under pressure D. Leclercq, C. Chevilliard, and R. Darras (*CEA–1407*, 1960, pp.43; from *Nucl. Sci. Abs.*, 1960, **14,** May, 1237) Tests on commercial steels under 25 atm. pressure, between 350 amd 600°C with comparative curves of oxidation kinetics showing the influence of various additive elements, are described.—S.H.-S.

The kinetics of the oxidation of iron at high temperatures and under low oxygen pressures. III. An analytical study of the isotherms and isobars of oxidation P. Belin (*Corros. Anticorros.*, 1960, **8,** April, 140–157) A mathematical and analytical survey of the first and second stages of oxidation, and of the influence of the pressure of oxygen (51 refs).—S.H.-S.

On oxide films on Fe–Si and Fe–Si–Al alloys at high temperature M. Sugiyama and T. Nakayama (*Nippon Kinzoku*, 1959, **23,** Sept., 534–538) Electron and X-ray diffraction methods were used to study alloys exposed to air at 700–1200°C. In the earliest stages of oxidation at 700° and 1000°C, heat-resisting films of amorphous oxides or fine Al_2O_3 crystals were formed. By reheating at 1200°C for 3 h these changed into α-crystobalite. Crystal layers of SiO_2 and Fe_2SiO_4 are formed inside Fe oxide scales on the surface of Fe–Si alloys oxidized at 1100°C and 1200°C.—K.E.J.

On oxide films of Fe–Cr–Al alloys at high temperature M. Sugiyama and T. Nakayama (*Nippon Kinzoku*, 1959, **23,** Sept., 530–534) Electron-diffraction studies were made on Fe–Cr–Al, Kanthal, and Fe–Cr JIS No.2 alloys exposed to air at 700–1000°C. Heat-resisting films of fine γ- and α-Al_2O_3 crystals were detected, and the effects of Al content, Cr content, and temp. on these were examined. Crystals of Cr_2O_3 and α-Fe_2O_3 produced at 700°C change into α-Al_2O_3 by the aluminothermic reaction at 1000°C (14 refs).—K.E.J.

Stress-corrosion cracking of Inconel in high temperature water H. Corion, R. Grall, M. Le Gall, and S. Vettier (*3rd Colloque Mét. Corrosion (1959, June–July)*, 1960, 161–169) [In French] Some Inconel samples were subjected to hot water corrosion testing (350°C) under stress slightly above the elastic limit. It was shown that different types of alloys with or without Ti could suffer serious intergranular damage and even complete rupture within three months.

The I.R.S.I.D. seawater corrosion testing station—principal results obtained at Biarritz A. Hache (*3rd Colloque Mét. Corros., Saclay, (1959, June–July)*, 202–204; from *Nucl. Sci. Abs.*, 1960, **14,** July 15, 1627) The reasons for the choice of Biarritz as the site of the seawater Corrosion Testing Station are given. The interest of the results obtained and the working facilities explain its extension.—S.H.-S.

Adsorption of radio-active sulphur on the surface of iron: Influence on electrochemical corrosion B. Le Boucher, C. Libanati, and P. Lacombe (*3rd Colloque Mét. Corros., Saclay, (1959, June–July)*, 1960, 205–215) [In French] Sulphur can be determined on the surface of iron at temp. around normal if this surface is not already covered by oxygen. The surface may be prepared by annealing in pure H_2 thus obtaining a well-defined condition. The quantity of sulphur determined is closely related to the crystal orientation; maximum for orientation grains (111), minimum for those about (110).

Corrosion of stainless steels by pure water at high temperature E. Pouillard (*3rd Colloque Mét. Corros., Saclay, (1959, June–July)*, 1960, 147–160) [In French] Tests on surface corrosion carried out both in the vapour and the liquid phase have shown that the steels studied showed good resistance to intergranular corrosion and that the predominant type of corrosion observed was pinhole. The number and depth of the pinholes were found to be related to the additive content of the surface examined. Corrosion under stress at 350°C is nil even after a year at a pressure of the order of $\frac{1}{2}$ $E_{0.2}$. However in the case of over-pickled steels appreciable intergranular corrosion developed.

'Knife edge' corrosion of certain stainless steel welds J. Hochmann (*Proc. 3rd Colloque Mét. Corros., Saclay, (1959, June–July)*, 171–174; from *Nucl. Sci. Abs.*, 1960, **14,** July 15, 1626–1627) Intergranular corrosion of Ti and Nb-stabilized stainless steels in HNO_3 adjacent to welds made at about 1300°C was observed. Attempts to explain this type of corrosion are made.

Certain factors in the corrosion of stainless steels in aqueous solutions L. Colombier (*Proc. 3rd Colloque Mét. Corros., Saclay, (1959, June–July)*, 111–125; from *Nucl. Sci. Abs.*, 1960, **14,** July 15, 1626) A study of some of the types of corrosion that can affect austenitic stainless steels, with a description of the practical solutions that can be applied.—S.H.-S.

Study of the precipitation of chromium carbide responsible for intercrystalline corrosion in austenitic stainless steels H. Hatwell (*Proc. 3rd Colloque Mét. Corros., Saclay, (1959, June–July)*, 137–146; from *Nucl. Sci. Abs.*, 1960, **14,** July 15, 1626) Correlation between the morphology of the chromium carbide precipitate $Cr_{23}C_6$, its conditions of growth in the alloy, and intergranular corrosion behaviour is attempted. Carbides of dendritic shape are shown to be chiefly responsible for intergranular corrosion, and appropriate modifications of Bain's theory (chromium depleted zone) are suggested.—S.H.-S.

Some examples of the use of the 'potentiostat' in study of the behaviour of metals in liquid media P. Berge and P. A. Jacquet (*3rd Colloque Mét. Corros., (1959, June–July)*, 175–184; from *Nucl. Sci. Abs.*, 1960, **14,** July 15, 1613) A brief description is given of a potentiostat modified by the addition of an automatic recording device and of a movable cell for non-destructive experiments on samples. Two types of application are described; the analysis of curves showing variation of polarization potential with intensity; and the analysis of curves for deducing the value of potential which when applied very often, makes it possible to control micrographic attacks very precisely.—S.H.-S.

A study of corrosion in the chemical section of a metallurgical coking plant J. Konšal and J. Teindl (*Hutn. Listy*, 1960, **15,** (7), 511–517) A study of corrosion of primary cooler tubes, of electrostatic tar separators, and of ammonium sulphate plant was made. Materials most suited for the construction of such auxiliary installations, as well as suitable protective coatings, are suggested.—P.F.

Study of metallic corrosion by X-ray diffraction O. Renius and G. P. Connell (*PB* 145011, 1959, Dec., pp.38; from *US Res. Rep.*, 1960, **33,** May 13, 549) Several metallic specimens, subjected to controlled corrosion, were studied to determine the crystal structure of the base metal and the corrosion products, diffraction patterns for various corroded and uncorroded, stressed, and unstressed metals being obtained. The relationship between diffraction peak-to-background intensity ratios and the extent of corrosion were investigated.—S.H.-S.

Short time corrosion tests of bronze, mild steel, T-304 stainless steel and 2 S aluminium in 10% potassium tetraborate solution Y. B. Katayama (*HW–23022*, 1951, Dec., pp.4; from *Nucl. Sci. Abs.*, 1960, **14,** May, 1237) The relative corrosion rates are determined, with tabulated data.—S.H.-S.

The behaviour of aluminium galvanically coupled to ferrous alloys in water at 200°F D. C. Belouin (*KAPL–M–DCB–3*, 1959, March, pp.16; from *Nucl. Sci. Abs.*, 1959, **13,** Aug. 31, 1949) Corrosion behaviour of C and stainless steel and Al galvanic couples was investigated after immersing for eight weeks in deoxygenated, deionized water and in tap water at 200°F.

Some metallurgical factors affecting stress corrosion cracking of austenitic stainless steels H. H. Uhlig and R. A. White (*NP–7602*, 1958, pp.28; from *Nucl. Sci. Abs.*, 1959, **13,** Aug. 31, 1951) Results of eight tests to failure of various steels in boiling 42%$MgCl_2$ are discussed, and the influence of C, N, Ti, Nb, Si, Co, and B in these steels on resistance to cracking is examined.

Metallurgical examination of a failed electromagnetic liquid metal pump channel G. H. Broomfield (*AERE–M/M–228*, 1959, March, pp.10; from *Nucl. Sci. Abs.*, 1959, **13,** Aug. 15, 1813) Examinations of the pump channel, which failed by cracking after 950 h service in an isothermal loop containing Pb–Bi eutectic, showed evidence of corrosion by the liquid metal. It was concluded that failure was due to fatigue, probably accelerated by corrosion.

Corrosion behaviour of aluminium–nickel–iron alloys in high temperature water under dynamic conditions G. J. Biefer and P. G. Anderson (*CR Met–799, AECL–763*, 1958, Dec., pp.65; from *Nucl. Sci. Abs.*, 1959, **13,** Aug. 15, 1814) Corrosion rates of $\sim 8 \times 10^{-3}$ in/year are obtained for these alloys in dynamic corrosion tests in deionized water at 260°C and 20 ft/sec linear velocity, if beds containing high areas of Al–Ni are used to saturate the loop water with dissolved corrosion water. Lower rates have been obtained by pre-treating the test specimens in high temp. static water. Mechanisms are proposed.

Corrosion of iron and steels in liquid metals. I. Static corrosion test Y. Imai and T. Ishizaki (*J. Atom. Energy Soc. Japan*, 1960, **2,** Feb., 96–101; from *Nucl. Sci. Abs.*, 1960, **14,** July 15, 1624) The modes of attack by liquid metals were investigated microscopically and the reliability of the experimental method was examined.—S.H.-S.

A sampling device for molten-salt systems W. B. McDonald and J. L. Crowley (*ORNL–2688*, 1960, March, pp.5; from *Nucl. Sci. Abs.*, 1960, **14,** June 15, 1337) The design and use of a sampling system which permits the removal of operating-fluid samples from a forced-circulation corrosion-testing loop while the loop is in operation are described. The device is mounted over the one free surface of the fluid and utilizes a dip tube which can be inserted into the liquid and removed without contaminating the inert cover gas of the system.—S.H.-S.

Chemical investigations in high temperature water loops J. K. Linacre and H. Morley (*AERE–C/R–2853*, 1959, Nov., pp.130; from *Nucl. Sci. Abs.*, 1960, **14,** June 15, 1361) A series of chemical investigations into the corrosion rate of a mild steel water loop are described in detail. The transfer of permanent gases from solution in the loop water to the vapour phase of a steam pressurizer was studied, relative to direct pressurizing, degassing, and gas absorption connexions of loop and pressurizer. Results were analysed in terms of a mechanism involving stripping of gas from the pressurizer liquid phase by steam bubbles rising from the immersed heater.

The reaction of iron with KCl–TiCl$_4$ melts in titanium vessels K. Blankenstein (*Techn. Mitt. Krupp*, 1960, **18,** Aug., 9–18) Ti coatings were obtained on low-C iron by heating the specimen in a KCl–Ti–Cl_2 melt in a sealed Ti vessel. The layer, containing up to 78 wt.-%Ti, consists mainly of β-Ti solid solution with dissolved iron. It protects the iron satisfactorily against 10%HNO_3, and its adhesion is good. The structure of the transitional diffusion zone is discussed (22 refs).

Study of the degree of passivity of 18-8 stainless steels. Special electrochemical behaviour of molybdenum 18-8 steel P. Berge (*Rev. Mét. Mém. Sci.*, 1960, **57,** Sept., 699–704) It is shown that the degree of passivation of specimens given various passivating treatments can be determined by coulometry in the case of 18-8 stainless steels subjected to a weak cathodic current in H_2SO_4; this method cannot

be applied to Mo-containing 18-8 steel, as its electrochemical properties differ greatly from those of ordinary 18-8 steel. The results are discussed.

The application of radioactive isotopes to the problems of metallic corrosion P. Lecombe (*Corros. Anticorros.*, 1960, **8**, June, 215–230) The selectivity and sensitivity of radioactive methods have considerably enlarged the field of study of corrosion problems. The chief forms of applications are the study of the segregation of impurities in the joints of grains, which are the causes of intergranular corrosion, heterogeneities of composition in alloys, and surface conditions of metals modified by the chemical or physical adsorption of certain elements, e.g. sulphur. The mechanism of corrosion inhibitors can also be accurately defined in a quantitative manner. Finally the kinetics of the dissolution of metals can be studied in its initial stages by means of the sensitivity of measurement. Examples of applications are shown, chiefly among ferrous metals.—S.H.-S.

The action of fused halides on nickel, copper, iron, and certain steels E. I. Gurovich (*Zhur. Prikład. Khim.*, 1960, **33**, (9), 2096–2101) On the whole, Cl^- exhibits a minimum corrosive effect. As a rule the greatest corrosion is caused by the action of F^- (on Armco iron, nickel, and type Kh18N9T steel).

Metal–water reactions. VI. Analytical formulations for the reaction rate L. F. Epstein (*GEAP*-3272, 1959, Sept., pp.52; from *Nucl. Sci. Abs.*, 1960, **14**, June 30, 1452) The various types of equations relating the extent of reaction between a metal and water vapour are reviewed and discussed. The parabolic rate law, and other rate laws, such as the cubic, logarithmic, and linear forms are considered. The dependence of the reaction rate on pressure and temp. is analysed and the effect of geometry on the rate law is discussed. Equations for determining rate and extent of reaction when temp. varies with time are considered.—S.H.-S.

A study of methods of assessment of the corrosion resistance of chromium–nickel austenitic steels in nitric acid H. N. Jones (*RDB (O)/TN*-16, 1952, Nov., pp.12; from *Nucl. Sci. Abs.*, 1959, **13**, April 30, 728) It is shown that austenitic Cr–Ni steels are more susceptible to attack along edges perpendicular to the direction of hot rolling. Rapid penetration occurs along slag stringers included in the steel. The effect of pretreatment on specimens, i.e. heat treatment, pickling, and polishing, were investigated and the weight loss method of estimating corrosion was compared with other methods.

Autoclave testing of type 304 stainless steel L. Frank and P. Eisenberg (*MND, E*, 1322–*T*, 1958, Nov., pp.14; from *Nucl. Sci. Abs.*, 1959, **13**, April 30, 726) Since oxygen is a major factor in stress-corrosion cracking it has been carefully controlled and a maximum allowable level for the performance in stress-corrosion cracking was determined. The stresses are shown to be about 34 000 to 39 000 psi at outer circumferential points measured on the U-bend.

Comparative data on the corrosion-resistance of selected types of 18-8 chromium–nickel stainless steels K. L. Sanborn (*HW* 32727, 1959, Feb., pp.27; from *Nucl. Sci. Abs.*, 1959, **13**, May 15, 1042) The conclusions were that there are many services at Hanford Atomic Products in which these steels may be applied interchangeably. It was recommended that the Huey test be imposed in specifications for the procurement of 18–8 Cr–Ni stainless steels used in all but specifically excepted separations service.

The effect of dissolved chromium on the corrosion–nickel–austenitic steels in boiling nitrid acid A. B. McIntosh, H. N. Jones, and J. A. S. Mowat (*Risley*–8012, 1951, Nov., pp.28; from *Nucl. Sci. Abs.*, 1960, **13**, June 30, 1504) The presence of hexavalent chromium can be prevented by ensuring the presence of nitrogen peroxide, thus decreasing the corrosion rate and improving the deviation of results in the boiling nitric acid test. A mechanism for the formation of hexavalent chromium is put forward and the effect on the electrode potential of the specimen in the acid is demonstrated.

Investigation of corrosion mechanisms in idle boilers and condensate systems F. E. Clarke and A. J. Ristaino (*AD*–204405; *PB* 145357, 1958, April, pp.54; from *US Res. Rep.*, 1960, **33**, June 17, 674) Partially filled tubes and conventional boiler water treatment chemicals are shown to contribute to corrosion in idle boilers. $NaNO_2$ appears to be the most promising chemical inhibitor.—S.H.-S.

Corrosion of 2R-2 and 304 stainless steel following the Turco 4501 decontamination process A. P. Larrick and R. J. Lobsinger (*HW*–59708, 1959, April, pp.17; from *Nucl. Sci. Abs.*, 1960, **14**, March 15, 579) The results using this process which consists of a highly alkaline film conditioning bath, a highly alkaline oxidizing bath, and a HNO_3 passivation bath, are described.

Corrosion resistance of CD4MCu stainless steel in reactor-related environments D. N. Hess, R. S. Greeley, P. D. Neumann, and J. C. Griess (*CF*–59–11–114, 1959, Nov. 30, pp.12; from *Nucl. Sci. Abs.*, 1960, **14**, Feb. 29, 485; *US Res. Rep.*, 1960, **33**, June 17, 711) The corrosion-resistance of CD4MCu steel, as-cast, rolled or heat treated, is greater than that of cast or wrought type 347 stainless steel in uranyl sulfate solutions at temp. up to 300°C. and equal to type 347 in most chloride-containing environments.

Effect of 1200°F sodium on austenitic and ferritic steels, thermal shock, nitriding, stressed corrosion, unstressed corrosion J. W. Mausteller and R. C. Werner (*MSA R*–59–99, 1959, Sept., pp.22; from *Nucl. Sci. Abs.*, 1960, **14**, Feb. 15, 353) Completion of preliminary designs for a thermal shock loop, a corrosion loop, and a nitriding loop is reported. Literature research showed that work has been done at 1200°F Na temp. with various oxygen concentrations but part of the data is contradictory. Test plans include corrosion testing of Croloy and stainless steel samples as well as welds of these materials in Na at 1200°F.

Recommended metal combinations to avoid galvanic corrosion E. D. Veilleux (*Mach. Design*, 1960, **32**, Feb. 18, 181–182) Galvanic corrosion can be minimized, if not eliminated, by combining two dissimilar metals of the least potential difference. A chart is given which grades metals from least corrosive to most corrosive to facilitate choice of metals with minimum potential difference.

An experimental study of erosion I. Finnie (*Proc. Soc. Expt. Stress Anal.*, 1960, **17**, (2), 65–70) An erosion tester with control of all the variables is described and measurement of a number of ductile and brittle materials including steels.

The reaction between concentrated nitric acid and carbon steel I. P. Mukanov, S. D. Beskov, and L. I. Kochetkova (*Zhur. Prikład. Khim.*, 1960, **33**, (9), 2084–2096) In studying the corrosion of carbon steels in highly concentrated solutions of HNO_3 it was found that, in addition to solutions of the metal, intercrystalline corrosion takes place, and that this causes destruction of the steel by erosion (11 refs).

***In situ* conversion of operating hydraulic oils to preservative oils** R. L. Le Mar (*Rept. No.*59–2773; *PB* 145114, 1959, Oct., pp.19; from *US Res. Rep.*, 1960, **33**, May 13, 549) Fourteen commercial, inhibitor, additive concentrates were evaluated in four samples of used, operating hydraulic oil, and a number of these concentrates converted such an oil to an inhibited oil with preservative properties comparable to MIL–L–21260 oil. These concentrates were also miscible with the oil at room temp. and so could be added directly to the oil in the machine tool hydraulic system and mixed therein, by starting up the machine tool. Viscosity and flash-point effects were also considered, and a list of quality control tests for future selection of concentrates is included.

Process quality control for corrosion preventive oils and compounds R. E. Johnson (*AD* 228438; *PB* 144735, 1959, Oct., pp.24; from *US Res. Rep.*, 1960, **33**, May 13, 549) A quality control programme to insure the quality of preservative materials used in the storage of ordnance material, and its results, are described. Periodic testing revealed deficiencies which were immediately corrected and a path to more economic storage was evolved.—S.H.-S.

Study of a newly developed inhibitor for ethylene glycol in storage C. B. Jordan (*COL*–86; *PB* 145683, 1959, Dec., pp.15; from *US Res. Rep.*, 1960, **33**, June 17, 672) A study showing the effect of inhibited ethylene glycol on unlacquered tin-coated steel after inspections at intervals of 2, 4, 6, and 8 months.

Protection of carbon steel from atmospheric corrosion L. D. Perrigo and R. G. Moles (*HW* 62466, 1959, Oct., pp.8; from *Nucl. Sci. Abs.*, 1960, **14**, June 15, 1361) Carbon steel coupons were exposed for two months under conditions of Hanford weather or to the atmosphere of a humidity oven at 150°F. Coupons coated with a proprietary compound rusted insignificantly, while the samples that were unprotected rusted severely in the Hanford climate and to a less degree in the humidity oven.—S.H.-S.

Inhibition of acid attack on steel by heavy metal ions J. A. Shropshire (*J. Electrochem. Soc.*, 1960, **107**, Sept., 740–744) Pb, Sn, and Cd are shown to inhibit the dissolution of steel. This appears to be due to the formation of a layer of sulphides on the steel surface. The protection is in the order of the sulphide insolubilities.

Inhibition of HNO_3–HF corrosion of type 304-L stainless steel with $Al(NO_3)_3$, $9H_2O$ W. L. Walker (*HW* 53636, 1958, April, pp.6; from *US Res. Rep.*, 1960, **33**, June 17, 711) No abstract.

A method of specimen corrosion protection for high temperature J. R. Bohn, R. E. Uhrig, and G. Murphy (*IS*–48, 1959, Oct., pp.17; from *Nucl. Sci. Abs.*, 1960, **14**, March 15, 580) This method involves encasing the creep specimen in a flexible capsule which is capable of withstanding exposure to the atmosphere for extended periods at up to 1 000°C. The capsule consists of several sections of bellows welded to machined parts which comprise the gauge point mounting rings and specimen end adapters.

The prevention of low-temperature corrosion with the help of ammonia-gas additions to combustion products O. M. Rabinovich and V. Ya. Gorbatenko (*Teploenergetika*, 1960, (10), 31–36) Experiments have shown that the addition of NH_3 to the combustion products lowers the dew-point temp. to the condensation temp. of pure water vapour, considerably reduces corrosion, and can be considered an effective and economical method of preventing corrosion.

The prevention of corrosion by brines A. Maringe (*Corros. Anticorros.*, 1960, **8**, May, 185–195; from *Revue Pratique du Froid*, 1957, Sept.–Oct.) The most usual types of corrosion are reviewed in order to deduce their principle causes and to advance remedies for them and, still better, to suggest measures for their prevention. Results are given derived from equipment in 15 plants where such measures were employed between 1942 and 1952.—S.H.-S.

The cathodic protection of ship bottoms for combating corrosion J. W. Boon (*Metaalinst. TNO Publn.* 75, pp.11; June, 1960, *Reprint from Schip en Werf*, 1960, **27**, May 27) After pointing out the various ways in which corrosion of ship bottoms can occur, the paper goes on to discuss the principles of cathodic protection and its application to coated surfaces in sea water. The various kinds of such installations are outlined. To conclude, the author reviews the published test results on the influence exerted by cathodic protection on coated surfaces in sea water available from the relevant technical literature.—F.E.H.

ANALYSIS

The detection of sources of error in analytical chemistry J. Agterdenbos (*Chem. Weekb.*, 1960, **56**, Aug. 20, 489–494) Four different sources of error may be encountered in analytical chemistry, those that are systematic or accidental and those the magnitude of which is independent of the quantity of the substance determined or proportional to this quantity. From statistical analyses of results given by suitable experiments, it is concluded that one of two of

these kinds of error predominate while others may be deemed negligible. The article describes how these statistical and also other methods may be employed for simplifying work of this nature.—F.R.H.

The present overseas situation in iron and steel analysis H. Goto (*Tetsu to Hagane*, 1960, **46**, May, 598–602) A review, including data on Mn, Si, Cr, Ni, Mo, Cu, V, Ti, Al, Co, Nb, B, Sn, Pb, As, Sb, Mg, Zr, W, and Ta.—K.E.J.

Flame-photometric methods in metallurgical analysis J. A. Dean (*Analyst*, 1960, **85**, Sept., 621–629) (57 refs).

Standardization. Standard test pieces. Rationalization in chemical analysis in iron- and steelworks E. Jaudon (*Rev. Mét.*, 1960, **57**, Aug., 731–734) The possibility of standardization of specimens is discussed with particular reference to British and American practice. The effectiveness of standardization in obtaining greater uniformity of results in iron and steelworks analysis is doubtful.

Metallographic Department (*Inst. Sper. Met. Leggeri*, 1958, Ann. Rep., 39–50) The work of the department consists of consultation on problems of aluminium alloy semis production, the uses of aluminium alloys, research on ferrous materials, and finally applied research. Research completed includes the following: research into foundry alloys G–AS7G and G–AS7GM, influence of iron on the abrasivity of Recidal 55 alloy, and research into Fe–Al alloys.

Melting shop control. An improved method of sampling liquid metals B. W. Berry and C. Clegg (*Iron Coal Trades Rev.*, 1960, **181**, Aug. 19, 395–397) Tests by a suction sampling technique using an evacuated sealed boro-silicate glass tube giving a wire 6–7 in long and rapidly quenched in water with greatly increased speed and economy of handling *en route* to laboratory analysis are described.

Device for taking liquid steel samples from steel baths E. V. Chelischkev and O. D. Zorin (*Russian Patent* 106258, 1955) The device consists of a silica tube into which steel is forced by ferrostatic pressure, with two openings, one to let air out, and the other closed by an Al bung to prevent penetration of steel before the Al melts. Several tubes can be used to obtain samples simultaneously from different depths in the bath.

Some tests on a commercial photoelectric titrator W. E. Clarke (*BCIRA J. Res. Dev.*, 1960, **8**, May, 351–359) The EEL Titrator is especially designed for the spectrophotometric detection of end-points. Tests carried out in the Association's laboratories indicate that the instrument is particularly suitable for rapid complexometric titration of Ca and Mg in limestone and slags. The advantages and limitations of the instrument are discussed and the results obtained are shown graphically.

Analytical methods for the inspection of iron powder (*PGR*–89 (*W*), 1960, Feb., pp.26; from *Nucl. Sci. Abs.*, 1960, **14**, June 30, 1468) A method for the quantitative analysis of iron powder is presented. Fe and P volumetrically, B spectrophotometrically, S and C by combustion (Cl, Si, grease, and particle size also).

The analysis of inoculated cast iron P. Répás (*Koh. Lapok-Ontöde*, 1960, **11**, June, 138–142) The author discusses the analysis of inoculated cast iron and of the various inoculants.—P.K.

Fractional methods for determining hydrogen in steel B. A. Shmelev (*Metody Khim. Analiza Mineral, Syr'ya*, 1957, **3**, 263–269; from *Nucl. Sci. Abs.*, 1960, **14**, Feb. 29, 455) Various pieces of apparatus used to study the release of H_2 from steel under vacuum at room temp. and during heating are described. Experiments showed that H_2 remaining in the crystal lattice after heating under vacuum is essentially molecular H_2 held in the metal pores.

New rapid vacuum fusion apparatus and steels L. C. Covington and S. J. Bennett (*Anal. Chem.*, 1960, **32**, Sept., 1334–1337) A simplified apparatus capable of completing 75 determinations in 8 h is described.

On the estimation of graphitic carbon in pig iron F. Marion and R. Faivre (*Chim. Anal.*, 1960, **42**, July, 355–359) The writers show that the determination of graphitic carbon by the classical method, i.e. separation by nitric attack and measurement of the CO_2 evolved after combustion in the electric furnace, is not accurate and suggest a new method based on a selective redox reaction of the cementite in contact with a hydrogen and steam atmosphere.

The determination of the carbon content of mild steels I. Sajó, J. Ujváry, and P. Répás (*Koh. Lapok*, 1960, **93**, July, 332–334) CO_2, the product of the combustion of carbon in the sample with oxygen, is absorbed by $Ba(OH)_2$, and the change in the conductivity of the solution measured.—P.K.

The colorimetric determination of vanadium with benzoylphenylhydroxylamine D. E. Ryan (*Analyst*, 1960, **85**, Aug., 569–574) Methods for steels and chrome ores are given and for chromite and chrome-magnesite.

Colorimetric determination of vanadium as vanadyl sulphate M. Kranz and J. Krzyzaniak (*Chem. Anal.*, 1960, **5**, (2), 243–246) A quantitative colorimetric analysis of V^{5+} can be carried out if it is previously reduced with SO_2 to V^{4+}. The resulting intense blue coloration of vanadyl sulphate can be measured. Solutions should be of concentration 0·05 mg to 0·7 mg per ml. They then obeyed Beer's law. Cr^{3+}, CO, Ti^{3+}, interfered with the determination and the effect was illustrated with graphs.

Spot test for cadmium in plating J. G. Sabo (*Chem. Anal.*, 1960, **49**, Sept., 78) NH_4NO_3 solution dissolves Cd preferentially and Na_2S solution is then added.

A review of methods for the determination of lead in cast iron R. C. Rooney (*BCIRA J. Res. Dev.*, 1960, **8**, May, 360–376) The effective methods of determining lead in cast iron are instrumental and evidence is produced to show that the direct polarographic methods are not satisfactory. The methods recommended use separation techniques with spectrophotometric or polarographic finishing procedures or emission spectrography using standards analysed by the recommended procedures.

Separation of rare earth elements in iron and steel H. Goto, S. Takeyama, and E. Sudo (*Nippon Kinzoku*, 1959, **23**, 267–270) A simple, rapid, and accurate method for analytical purposes is described. Fe is extracted with methyl *iso*butyl ketone, and the remaining Fe and Cr are separated by electrolysis. Rare-earth elements are pptd. as fluorides. A modification is given for samples containing W.

The determination of a minute amount of zinc in stainless steels W. Sekimoto, H. Iwamoto, and K. Oda (*Nisshin Seiko Giho*, 1959, Dec., 29–35) The use of dithizone is a new and easy method for isolating zinc prior to its determination in cast iron and carbon steels. Successful results were obtained by using the mono-color dithizone method on stainless steels.

The future of steel analysis D. F. Sermin (*New. Sci.*, 1960, **8**, July 7, 42–44) A general account of spectrographic methods.

Investigations on the statistics of the fluctuations of line intensities in periodic spark discharges H. Krempl and H. Späth (*Arch. Eisenh.*, 1960, **31**, Aug., 473–477) Changes of intensity in spectral lines in a condensed spark discharge were measured by means of the equipment described, and the causes of the observed fluctuations examined. These causes include the fluctuating condenser potential U_c in the uncontrolled spark, and movement and burning in of the spark on the electrode surface.

Spectrographic analysis of high alloy deposit metal E. S. Kudelya (*Avtom. Svarka*, 1960, (3), 76–79) A new method is described of wider applications for the analysis of Cr–Ni austenitic steels and welding joints. The source of light is a high-frequency spark alternator of the design of the Institute for Electrowelding. A 0·4 amp current is supplied by the alternator at 3500 V in the secondary winding. Capacity of the shunt condenser 100 picofarads, width of the slit 0·02 mm.

Rapid determination of chromium by differential spectrophotometry K. Hirokawa (*Nippon Kinzoku*, 1959, **23**, July, 371–373) Cr in FeCr and high-Cr alloys is determined by measuring the absorbence in N–$HClO_4$ at 350 mμ against a reference soln. No interference is found from Fe, Ni, or Mn up to 50% or Ti or Co up to 20%. Fe above 50% is removed by solvent extraction.

Automatic derivative spectrophotometric titration of excess EDTA in the determination of cobalt, copper or iron H. V. Malmstadt and T. P. Hadjiioannou (*Anal. Chim. Acta.*, 1960, **23**, Sept., 288–293) Calcein W is used as indicator at 500 mμ in an automatic titrator.

3, 3', 4', 5, 7- Pentahydroxyflavanone as a reagent for spectrophotometric determination of molybdenum in steel F. L. Chan and R. W. Moshier (*WADC–TN–59–265*, 1959, July, pp.9; from *Nucl. Sci. Abs.*, 1960, **14**, June 30, 1469) A colorimetric method for determining Mo in steel. By an extraction process, all interfering metals except W are removed. The procedure will determine Mo in all substances except W.—S.H.-S.

The use of special atmospheres in spectrographic analysis R. Farský (*Hutn. Listy*, 1960, **15**, (7), 548–552) The advantages of using inert or other special atmospheres in certain analyses are discussed, and the recent literature is surveyed. A spark chamber for use with protective atmospheres, designed by the author, is shown.—P.F.

Experiences with secondary X-ray emission analysis in the determination of high tungsten contents in steel O. Bélohlávek and J. Lažanský (*Hutn. Listy*, 1960, **15**, (7), 546–548) The industrial use of a quantometer of Czechoslovak design for the rapid determination of W in high-speed steels is discussed. The instrument has given good service for the two years since its installation. Sampling of melts and sample preparation for the analysis are considered.—P.F.

Spectrophotometric determination of beryllium in stainless steels S. Wakamatsu (*Nippon Kinzoku*, 1959, **23**, Sept., 522–525) An accurate and precise method for traces of Be is based on its reaction with aluminon in the presence of a sequestering agent which removes interfering elements, e.g. Al, V. A red-coloured complex with absorption peak at 530 mμ is formed. The system obeys Beer's Law in the range 0·01–0·1 mg of Be. Interference by Fe, Ni, Cr, etc., is eliminated by the magnetic mercury cathode method.—K.E.J.

Determination of rare earth elements in iron and steel H. Goto, S. Takeyama, and E. Sudo (*Nippon Kinzoku*, 1959, **23**, May, 270–273) Ce and La are isolated from the rare-earth elements by standard methods. Ce is oxidized to Ce^{3+}, methylene blue is added, and the absorbency is measured at 510 mμ in a benzene extract. La oxide is dissolved and determined by a flame method.—K.E.J.

Spectrophotometric estimation of traces of selenium in steels. II N. Léontovitch (*Chim. Anal.*, 1960, **42**, July, 329–335) This article describes a method of separating Se from the various steel constituents in order to carry out a photometric estimation. Estimation can be made in presence of any amount of Mn, Ni, Cr, Mo, V, P, and S, but in presence of Si, W, Zr, Nb, and Ta, these have first to be converted to complexes.

Determination of small amounts of special elements in cast iron. III. Spectrophotometric determination of tellurium in cast iron K. Ota (*Nippon Kinzoku*, 1959, **23**, Oct., 581–584) Details are given for the adaptation of the basic thiourea method to the determination of Te in iron. Absorption at 350 mμ is most suitable. The preliminary separation of Te was made in 3N HCl using $SnCl_2$. Other elements in normal cast iron do not interfere (11 refs).

The spectrographic determination of rare earths in ferrous sulphate (concentration) C. J. Riley and S. Newton (*SCS–R–252*, 1951, July, pp.8; from *Nucl. Sci. Abs.*, 1960, **14**, June 15, 1323) A method is given for determination of rare earths in ferrous sulphate, consisting of double co-precipitation of the rare earths with Ca $(COO)_2$ followed by double co-precipitation with $Fe(OH)_3$.—S.H.-S.

Spectrum excitation impulse generators and their use in spectrographic quantitative analysis of silicates E. E. Vajnstejn and V. V. Korolev (*Chim. Anal.*, 1960, **42**, Oct., 479–489) The use of spectrum excitation impulse generators has made it possible during recent years to improve the accuracy of the analysis of silicates. The writers describe these generators in detail and examine the experimental results obtained.

Use of radioactive isotopes of arsenic and niobium for investigations of metallurgical reactions M. L. Sazonov and L. A. Schwarzman

(*Internat. J. Appl. Radiation & Isotopes*, 1960, Feb., 311–316; from *Nucl. Sci. Abs.*, 1960, **14**, June 30, 1506) Methods for investigation of As and Nb distribution between iron and slag are studied. The technique used for removal of radioactive admixtures and identification of radioactive isotopes is emphasized. Thermodynamic data characteristic of oxidation of As and Nb dissolved in liquid iron are given.

On the determination of FeO in chromium ores and in chrome–magnesite B. Brežný (*Hutn. Listy*, 1960, **15**, (7), 552–554) A method for the determination of FeO, in the presence of Fe_2O_3, simpler and quicker than current methods, is described. The sample is dissolved in a 4:1 mixture of phosphoric and sulphuric acids in the presence of excess $Ce(SO_4)_2$. The ceric sulphate not used up in the oxidation of ferrous ions is back-titrated potentiometrically.—P.F.

Rapid determination of total iron and total manganese in slag by fluorescent X-ray spectroscopy K. Hirokawa (*Nippon Kinzoku*, 1959, **23**, July, 376–380).—K.H.J.

The determination of iron in low grade uranium ores A. Parker (*AERE–AM–59*, 1959, July, pp.5; from *Nucl. Sci. Abs.*, 1960, **14**, March 31, 658–659) After digesting the finely ground ore in aqua regia; the Fe is reduced and titrated with $K_2Cr_2O_7$.

Rapid method of determining Fe_2O_3 in a ferrous–limestone mixture E. V. Khitro, M. I. Kostomarov, and L. I. Ostapchuk (*Ogneupory*, 1960, (5), 237–238) At the Petrouralsk Dinas Works, pyrites cinders are used to mineralize a ferrous–limestone dross and sulphate liquor. A rapid analysis of the Fe_2O_3 content is proposed.

Determination of chromium in calcium fluoride mould lining G. Robertson (*SCS–R–172*, 1951, May, pp.11; from *Nucl. Sci. Abs.*, 1960, **14**, March 31, 661) CaF_2 is decomposed with fusion mixture and Cr leached out with water, then determined colorimetrically with diphenylcarbazide.

Study on chemical analysis of basic slag. IV. Determination of P, Cr and V in basic slag S. Wakamatsu (*Tetsu to Hagane*, 1960, **46**, April, 492–497) Full data are given of simple spectrophotometric methods for determining P_2O_5, Cr_2O_3, and V; the last is determined from an aliquot of the solution used for Cr_2O_3 (12 refs).

INDUSTRIAL USES AND APPLICATIONS

The industry's research task. I. Anticipating the designer W. E. Bardgett and K. J. Irvine (*Financial Times*, 1959, Aug. 10, VIII) Research for newer industrial uses including atomic plant and guided missiles is indicated.

Stainless steel in building and architectural decoration. II A. G. Amoroso (*Acciaio Inossid*, 1960, **27**, July–Aug., 466–480) Numerous practical examples are given together with a list of structures using stainless steels completed in Italy.

Deep-drawing non-ageing steel for the motor car industry J. Bečvář and M. Zezulová (*Hutník*, 1960, **10**, (8), 303–307) On the basis of a critical survey of the present state of knowledge relating to non-ageing steels for deep-drawing, it is concluded that killed steel made in the acid converter, or produced by the O_2+H_2O process in the basic converter, or possibly also in the OH furnace if followed by vacuum degassing and ladle deoxidation, would be most suitable for deep-drawing sheet of comparatively high strength. The effect of production technology and composition on the drawability and other mechanical properties of the sheet are discussed.—P.F.

A wide variety of steel tubes in universal use A. G. Stewart (*Financial Times*, 1959, Aug. 10, VII) Uses are briefly referred to.

Hot-formed coil spring manufacture R. Haynes (*Metallurgia*, 1960, **62**, July, 21–28) A survey, giving accepted up-to-date production methods.—S.H.-S.

Sheet and tinplate for the car and canning lines H. F. Spencer (*Financial Times*, 1959, Aug. 10, V) With a few statistics.

A metallurgical approach to grinding ball production J. G. Underwood (*Trans. Canad. Inst. Min. Met.*, 1959, **62**, 148–153) Factors of composition and heat-treatment influencing hardness and hardenability are discussed. Resistance to abrasion and impact is measured, but actually only performance in the mill is conclusive.

High temperature bearing materials O. W. McMullan (*Mach. Design*, 1960, **32**, Feb. 18, 184–189) This article describes the various types of steel used in the majority of anti-friction bearings and their heat treatment. It includes a table giving the composition of high temp. steels.

Materials control is crux of watch production D. Fishlock (*Metalw. Prodn.*, 1960, **104**, Sept. 7, 81–82) The steels used are considered in particular.

Future application trends for titanium and steel in military aircraft W. S. Lyman and F. L. Bagby (*DMIC–Memo–17*, 1959, May 8, pp.6; from *Nucl. Sci. Abs.*, 1959, **13**, Aug. 31, 1949) An investigation of future trends in the uses of steel and Ti in military aircraft, with a summary of the results and conclusions.

Marine propellers of stainless steel (*Acciaio Inossid*, 1960, **27**, July–Aug., 481–483) This is a note prepared by the Avesta steelworks on the production of propellers using stainless steel Avesta 7395. The advantages are, less risk of galvanic corrosion than with bronze, reduction in galvanizing costs, and no need to replace the propeller when sailing through ice as is the case with bronze propellers. Tables are given which compare the characteristics of the various materials used for propellers.

Staff study on adequacy of research programmes on high strength steels for elevated temperature applications in aircraft E. V. Bennett (*MAB–53–SM*, 1959, Oct. 30, pp.68; from *Nucl. Sci. Abs.*, 1960, **14**, Feb. 15, 349) 109 airframe research projects were located and reviewed indicating a programme adequacy much better than anticipated, with comparatively little duplication of effort.

Development of a corrosion-resistant bearing steel for service in aircraft at temperatures up to 1 000°F G. Steven and T. V. Philip (*WADC–TR–59–390*, 1959, July, 68; from *Nucl. Sci. Abs.*, 1960, **14**, April 15, 841) Composition and heat treatment are described of a high-speed type bearing alloy which has been modified with V, W, Mo, and Co to produce corrosion resistance in addition to high initial hardness, adequate temper resistance (600–900°F), and good dimensional stability. Composition recommended for a stainless bearing steel for use at temp. up to 900°F for 500 h is 1·10–1·15%C, 0·15%Mn max., 0·15%Si max., 13·5–14·5%Cr, 2·5–3·0%V, 2·0–2·5%W, 3·75–4·25%Mo, and 5·0–5·5%Co.

Fabrication of stainless steel–uranium dioxide fuel elements J. R. Keelar (*BMI–904*, 1959, Aug., pp.28; from *US Res. Rep.*, 1960, **33**, May 13, 587) No abstract.—S.H.-S.

Choice of steel for the R3/Adam pressure vessel O. Källbäck (*NP–8386*, 1959, Sept., pp.15; from *Nucl. Sci. Abs.*, 1960, **14**, June 15, 1359) The R3/Adam reactor is described, and the development of an acceptable C–Mn steel for use in the pressure vessel is discussed along with stainless steel for vessel cladding. Data on steel specifications are included.—S.H.-S.

Nickel–chromium–iron alloy bars and forgings: corrosion resisting for radioactive system service C. F. Barrett jun. (*KAPL–SPEC–KPM3–49*, 1958, Sept., pp.7; from *US Res. Rep.*, 1960, **33**, June 17, 713) No abstract.

Transcripts of symposium on economic comparison of zirconium and stainless steel in nuclear power reactors M. Benedict and J. W. Blanton (*NP–7261*, 1958, pp.107; from *Nucl. Sci. Abs.*, 1959, **13**, May 15, 1044) These papers describe the procedures, assumptions, and results of studies on the economics of Zr versus stainless steel as structural and cladding materials for five different types of power producing reactors and Zr mill products respectively.

Development of swaged stainless steel fuel rods containing UO_2 J. T. Lamartine and W. C. Thurber (*CF–59–10–8*, 1959, Oct., pp.46; from *US Res. Rep.*, 1960, **33**, June 17, 711) No abstract.

HISTORICAL

From heavenly metal to the Wieland Saga E. H. Schulz (*Werk und Wir.*, 1959, **7**, Nov.–Dec., 368–371) This article describes methods used from prehistoric times to the Middle Ages in smelting iron and hardening iron tools and weapons as evidenced by early writings and the examination of iron relics.

125th Anniversary of the Ruegenberg Works in Olpe (*Wirk und Wir.*, 1959, **7**, Oct.–Nov., 338–345) This article describes the growth of the Ruegenberg Works of Hoesch AG up to the present day, with special reference to the personalities who played their part in its development.

Historical sketch of the Lynchburg Foundry Company (*Iron Worker*, 1959/60, **24**, Winter, 3–7) This article describes the production of the first cast iron gas and water pipes by the above Company and its growth up to 1918.

History of Nisshin Steel Works Ltd (*Nisshin Seiko Giko*, 1959, Dec., 1–2) [In Japanese].

A great French metallurgist. L. J. Troost (*Aciers Fins. Spéc.*, 1960, July, 106–108) The life and work of Troost are summarized, special mention being made of his research into the structures of C, Si, Ti, B, Zr, Nb, and Ta. His conclusions regarding the role of Si and Mn in iron metallurgy are referred to.—R.P.

ECONOMICS AND STATISTICS

U.K. steel markets (*Met. Bull.*, 1960, No.1, 16–18) Notes on expansion of plant, supplies, output, and demands of the five steelmaking areas.

The market for heavy steel and re-rolled products T. R. Craig (*Financial Times*, 1959, Aug. 10, IV).

Development plans soundly based Sir Ellis Hunter (*Financial Times*, 1959, Aug. 10, I) A brief account of the companies' policies during and since nationalization.

Gross output of French fine and special steels (*Aciers Fins. Spéc.*, 1960, July, 87) The table shows increases in production of various special steels in France between 1938 and 1959.

Calculating the effectiveness of capital investment in the mechanization and automation of production V. O. Chernyavskii (*Stal'*, 1960, (10), 954–956) A general discussion of economics.

Dynamic management for profit A. E. McDonough and G. H. Krapf (*Iron Steel Eng.*, 1960, **37**, June, 117–121) A description of a plan for interdepartmental co-operation put into practice at the South Works, Chicago, of United States Steel Corp.

MISCELLANEOUS

Data processing as related to the steel plant H. R. Berke (*AISI*, 1960, preprint, pp.8) An outline of the use of computers.

The iron and steel industry Wurth (*Techn. Human.*, 1959–60, **57**, (6), 36–39) This article briefly describes the qualities required of a metallurgical engineer in the iron and steel industry and his prospects.

Study on the production of metallic magnesium by the reduction method. III. On the effect of some additions and calcining temperature on reduction of dolomite by FeSi M. Ikeda (*Nippon Kinzoku*, 1959, **23**, Aug., 437–441) Addition of NaF, NaCl, $3NaF.AlF_3$ or $CaCl_2$ decreases the yield of Mg, but addition of CaF_2, fluorite, or MgF_2 increases it. CaF_2 is better than MgF_2, but the latter is superior as a binder for dolomite briquettes. The max. Mg yield is obtained at temp. near 1 000°C.

Automation, of course; but how far, how fast? R. E. Blackwell (*Steel*, 1960, **147**, July 4, 68–71) Examples of electronic equipment in steelplant are given. Caution in their adoption is advised.—S.H.-S.

On the counter-plan for hot environment in an iron and steel works. II. Experimental study of water curtain T. Nakano, T. Fujimoto, A. Yoshida, and S. Terao (*J. Lab. Hyg.*, 1960, **9**, May, 11–16) Studies of the wire netting used and the volume of water were made. About 80% of the radiant heat was absorbed and the above variables had little effect.

Life tables for the workers and their families of Yawata iron and steel works 1956–1958 H. Mizushima, N. Hata, N. Motoda, M. Kawai, S. Shinjo, and T. Shigematsu (*J. Lab. Hygiene*, 1960, **9**, Aug., 21–29).

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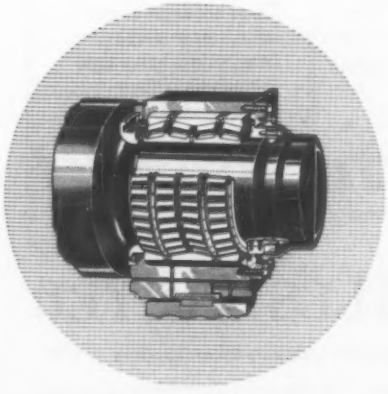

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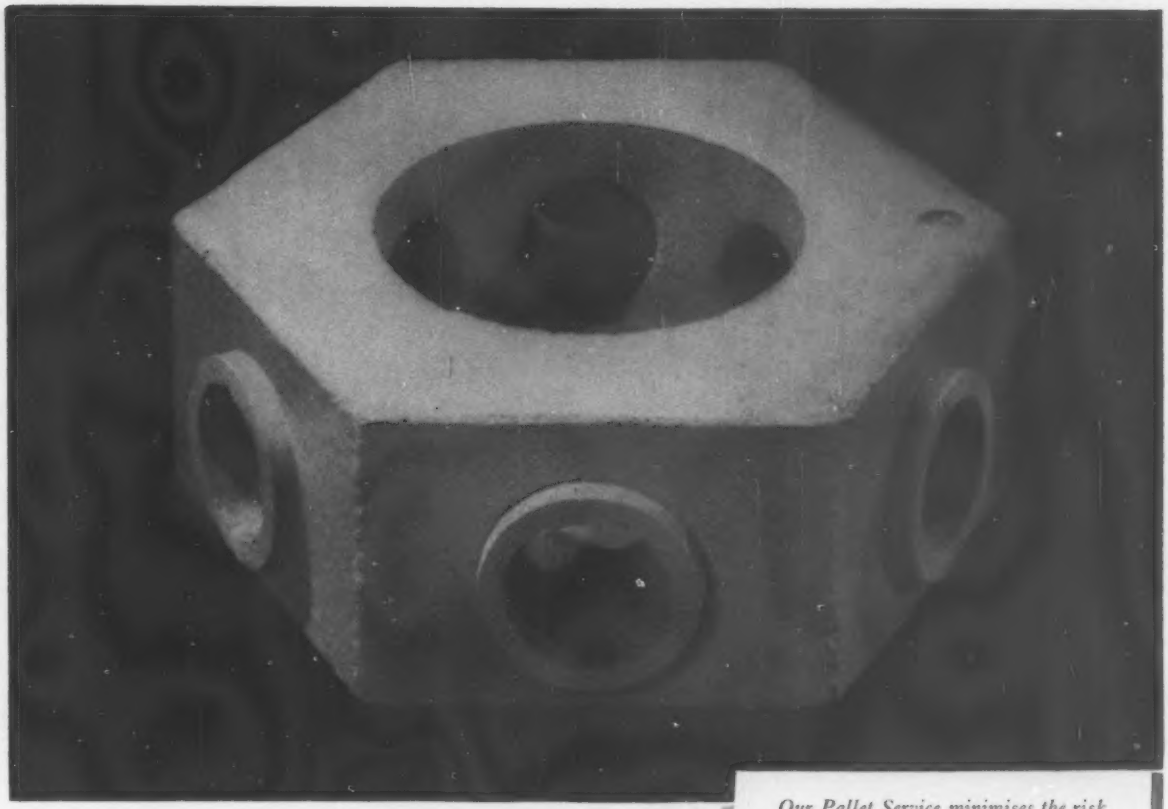

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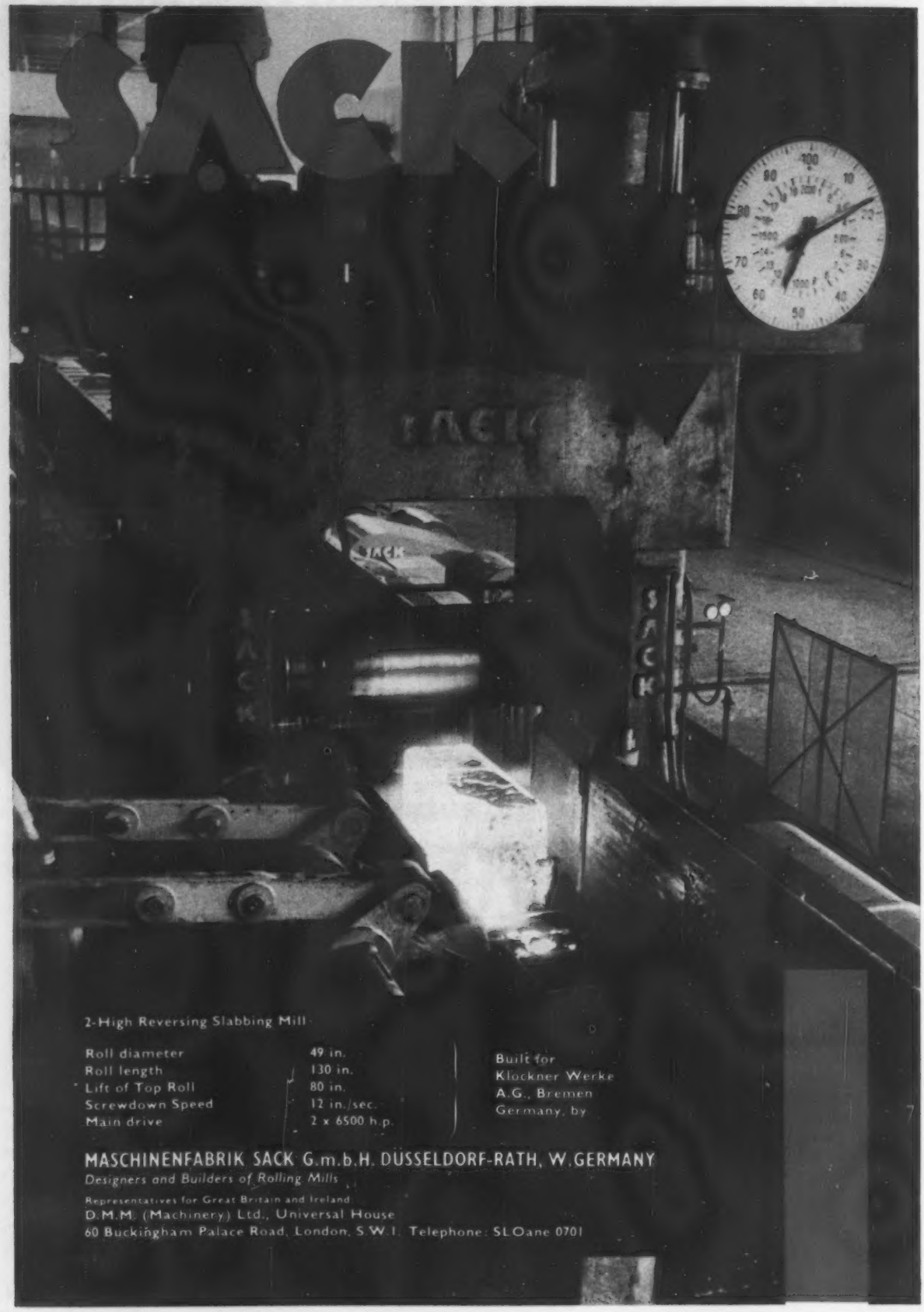

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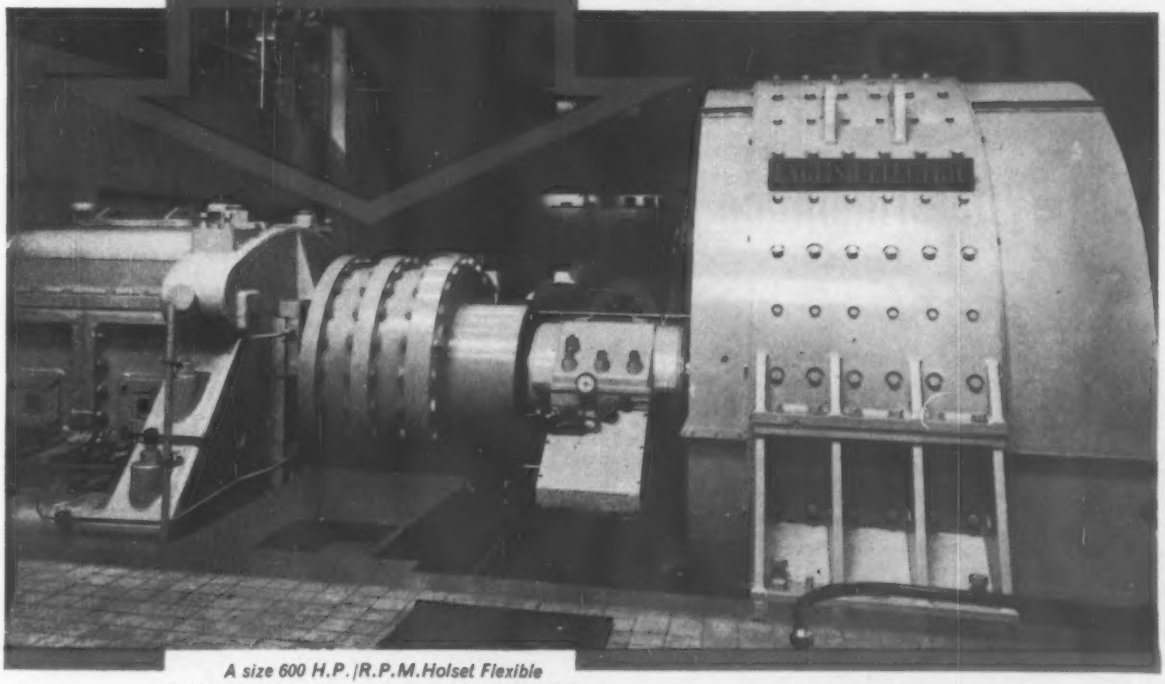

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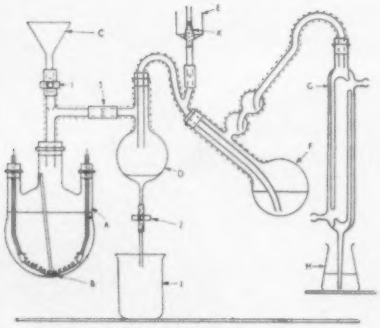

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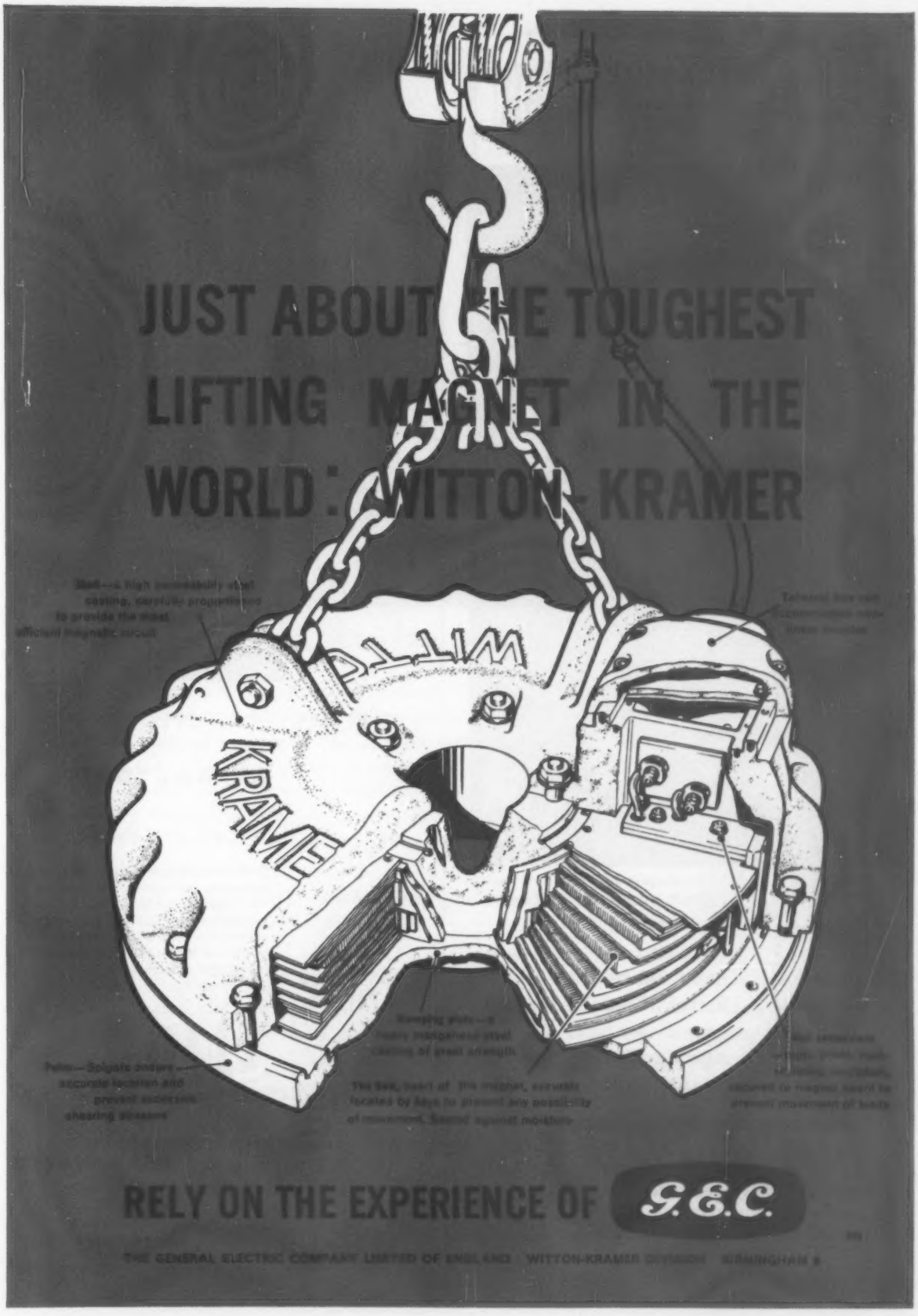
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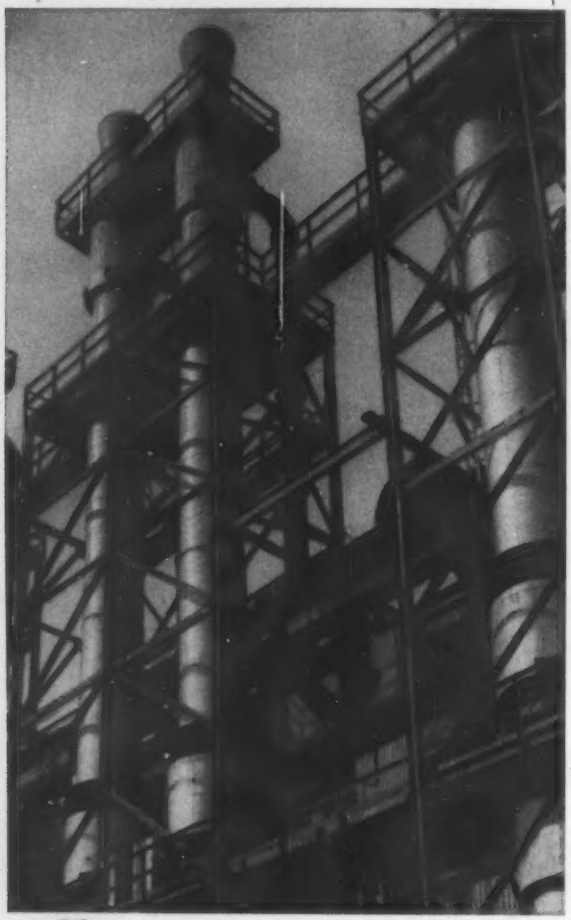

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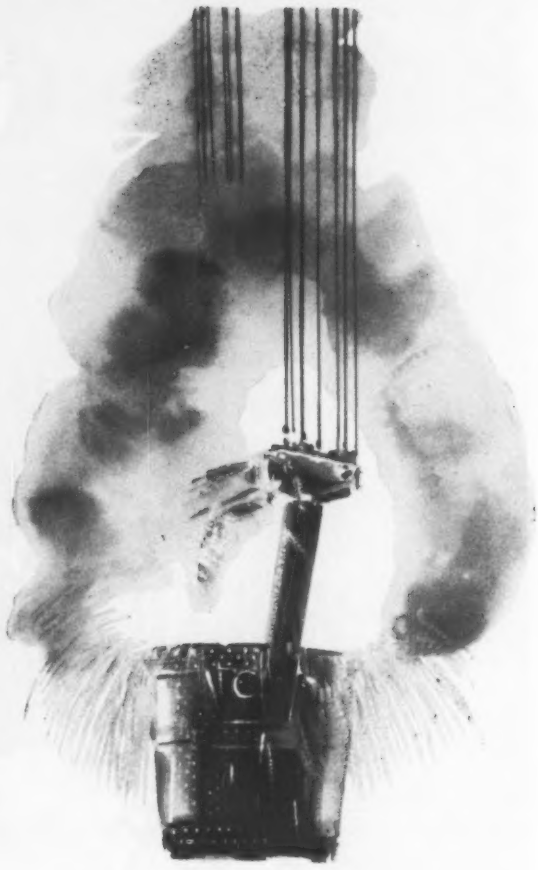

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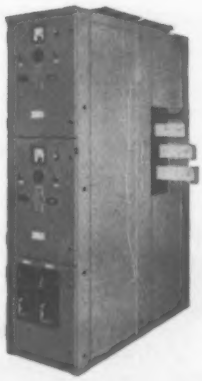

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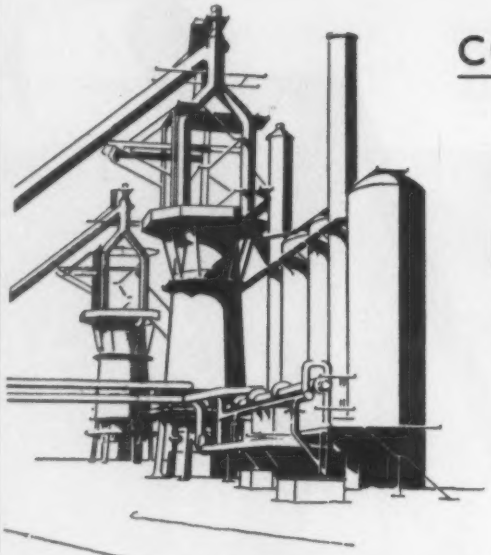

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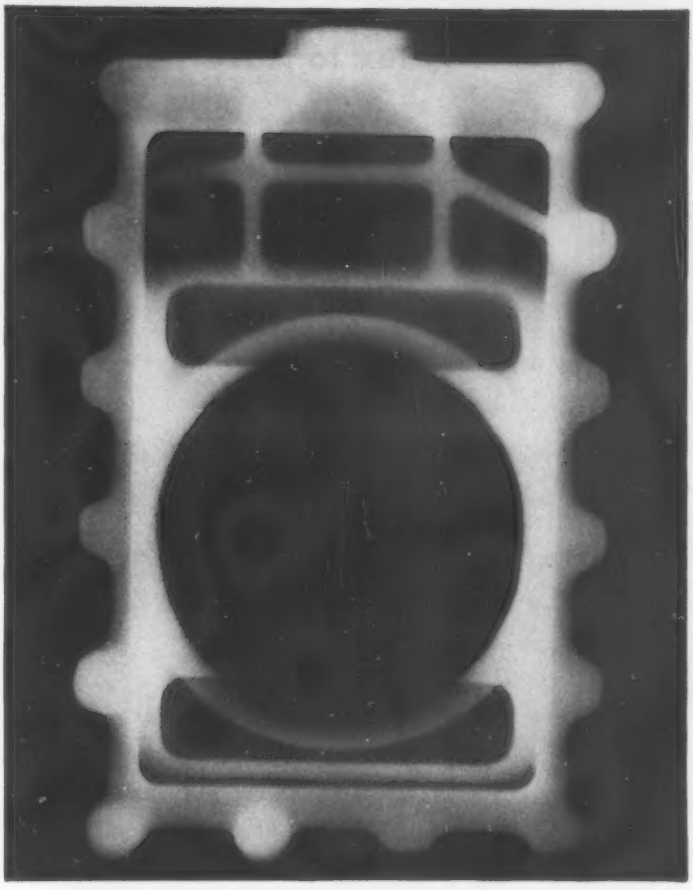

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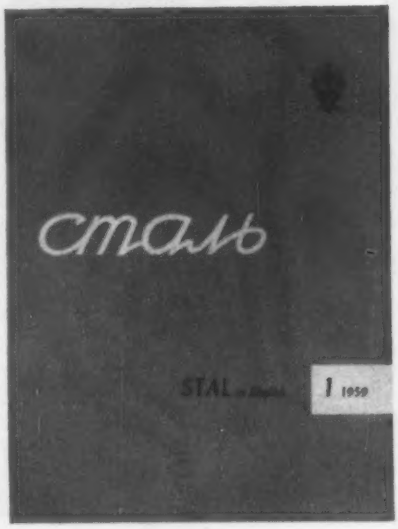

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Index to Advertisers

Continued from page 90

Salem-Brosius (England) Ltd. . . —
Schieldrop & Co. Ltd. 43
Schloemann AG . . . . . —
Senior Economisers Ltd. . . . 47
Shaw, John (Salford) Ltd. . . —
Sheepbridge Equipment Ltd. . . —
Shell-Mex & B.P., Ltd. . . 40, 41
Sheppard & Sons Ltd. . . . . —
Simon-Carves Ltd. 35
Skefko Ball Bearing Co. Ltd., The . —
Smith, John (Keighley) Ltd. . . 24
Smith & McLean Ltd. 14
Smith, Thomas, & Sons (Rodley) Ltd. —
Spencer-Bonecourt-Clarkson Ltd. . —
Stanton Ironworks Co. Ltd., The . —
Steel Co. of Wales Ltd., The . . 76
Steel, Peech & Tozer Ltd. . . . —
Stein & Atkinson Ltd. . . . . —
Stein, John G., & Co. Ltd. . . —
Stephens Silica Brick Co. Ltd. . . 80
Stewarts & Lloyds Ltd. . . . . —
Stillite Products Ltd. 37
Strachan & Henshaw Ltd. . . —
Sturtevant Engineering Co. Ltd. . 53
Summers, John, & Sons Ltd. . . —
Summerson, Thos., & Sons Ltd. . —

Tattersall & Sons Ltd. 86
Thermal Efficiency Ltd. . . . . —
Thermal Syndicate Ltd. . . . . —
Thomas (Richard) & Baldwins Ltd. . —
Thornton, B., Ltd. 62

Union Carbide Ltd. 3
United Coke & Chemicals Co. Ltd. . —
United Steel Companies Ltd. . 9, 10, 11

Vaughan, Edgar, & Co. Ltd. . . . —
Visco Engineering Co. Ltd. . . 32

Ward, Thos. W., Ltd. 65
Warner & Co. Ltd. 21
Wellman Bibby Co. Ltd., The . . —
Wellman Smith Owen Engineering Corporation Ltd., The . . . 1
West Hunwick Silica & Firebrick Co. Ltd. 26
West Instrument Ltd. . . . . —
Whipp & Bourne Ltd. . . . . —
Whitehead Iron & Steel Co. Ltd. . 89
Wild-Barfield Electric Furnaces Ltd. —
Willan, G. L., Ltd. . . . . —
Wincott, G. P., Ltd. 20
Woodall-Duckham Construction Co. Ltd. 72
Workington Iron & Steel Co. . . 11
Wragg, Thos., & Sons Ltd. . . 77

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Index to Advertisers

Adamson-Alliance Co. Ltd. . . . 25
Adamson, Joseph, and Co. Ltd. . 64
Air Products (Gt. Britain) Ltd. . —
Akers Styckebruk . . . . . —
Allen West & Co. Ltd. . . . 31
Appleby-Frodingham Ltd. . . . —
Armstrong-Whitworth (Metal Industries) Ltd. 58
Arrol, Sir Wm., & Co. Ltd. . . —
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British Acheson Graphite Ltd. . . 15
British Electrical Development Association 18
British Furnaces, Ltd. . . . 68
British Iron & Steel Federation, The 66
British Paints Ltd. 38
British Railways, Eastern Region . 82
British Rollmakers Corporation Ltd. —
British Timken: Division of the Timken Roller Bearing Co. . . 75
Brookhirst Igranic Ltd. . . . —
Brown Bayley Steels Ltd. . . . 56
Buell Ltd. . . . . —
Burn Fireclay Co. Ltd., The . . —
Bushing Co. Ltd., The . . . 17

Carblox Ltd. . . . . —
Colville Group of Companies, The . 12
Consett Iron Co. Ltd. . . . 44
Contactor Switchgear Ltd.. . . 49
Coppee Co. (Gt. Britain) Ltd., The . —
Cowans Sheldon & Co. Ltd. . . —
Craven Bros. (Crane Division) Ltd. . —
Crooks, L. E. 90

D.M.M. Machinery Ltd. 78
Davy-Ashmore Ltd. 74
Deloro Stellite Ltd. 45
Demag . . . . . —
Derbyshire Stone Quarries Ltd. . —
Dewhurst & Partner Ltd. . . —
Distington Engineering Co. Ltd. . 10
Dyson, J. & J. Ltd. Inside Front Cover

Edwards High Vacuum Ltd. . . . 29
Efco Furnaces Ltd. . . . . —
Eimco (Great Britain) Ltd. . . 55
Electroflo Meters Co. Ltd. . . . —
English Electric Co. Ltd., The . . 85
English Steel Castings Corporation Ltd. 30

Fielding & Platt Ltd. . . . . —
Firth, Thomas, & John Brown Ltd. 48
Foster, Henry & Co. Ltd. . . . —
Foster Instrument Co. Ltd. . . —

G.W.B. Furnaces Ltd. 57
Garringtons Ltd. . . . . —
General Electric Co. Ltd., The . . 83
General Refractories Ltd. . . . 51
Gibbons Brothers Ltd. . . . —
Gibbons (Dudley) Ltd. . . . 79
Great Lakes Carbon International Ltd. 6
Guest, Keen Iron & Steel Co. Ltd. . 54
Guest, Keen & Nettlefolds Ltd. . 16

Hadfields Ltd. . . . . —
Hastie, Bernard, & Co. Ltd. . . 84
Head Wrightson, Iron & Steel Works Engineering, Ltd. 46
Head Wrightson Minerals Engineering, Ltd. 27
High Speed Steel Alloys Ltd. . . —
Holmes, W. C. & Co., Ltd. . . 59
Holset Engineering Co. Ltd., The . 81
Honeywell-Controls Ltd. . . . —
Howden, James, & Co. Ltd. . . —
Huntington, Heberlein & Co. Ltd. . 50

Ilford Limited 87
Imperial Chemical Industries Ltd. . —
International Combustion Products Ltd. . . . . —
International Construction Co. Ltd., The 52
International Nickel Co. (Mond) Ltd. 34

Johnson Matthey & Co. Ltd. . . . 61
Johnson's Rolls Ltd. 39

Kestner Evaporator & Engineering Co. Ltd. 86
Kingscliffe Insulating Products Ltd. 60

Lamberton & Co. Ltd. Outside Back Cover
Lanarkshire Steel Co. Ltd., The . —
Lancashire Steel Manufacturing Co. Ltd. 69
Laurence, Scott & Electromotors Ltd. —
Lodge-Cottrell Simon-Carves . . —
Loewy Engineering Co. Ltd., The . 4
Lysaght's, John, Scunthorpe Works Ltd. 5

Macdonald & Evans Ltd. 68
Marshall, Thomas, & Co. (Loxley) Ltd. . . . . —
Metallurgical Engineers Ltd. . . —
Mitchell Engineering Ltd. . . . —
Mobil Oil Co. Ltd. 42
Moorwood, John M., Ltd. . . . —
Morgan Refractories Ltd. . . . 8
Morgardshammars Mekaniska Verkstads AB . . . . . —
Moxey Ltd. . . . . —

National Coal Board, The . . 22, 23
National Industrial Fuel Efficiency Service . . . . . —
Newell, Ernest, & Co. Ltd. . . —
Newton, Chambers & Co. Ltd. . . —

Oughtibridge Silica Firebrick Co. Ltd. . 70

Pantin, W. & C., Ltd. 63
Park Gate Iron & Steel Co. Ltd. . —
Parsons, C. A., & Co. Ltd. . . —
Pearson, E. J. & J., Ltd. . . . 84
Pickford Holland & Co. Ltd. . . 67
Power-Gas Corporation Ltd., The . —
Power Petroleum Co. Ltd., The . —
Press, William, & Son Ltd. . . —
Priest Furnaces Ltd. 33

RN Process Agency . . . . . —
Railko Ltd. . . . . —
Rawlplug Co. Ltd., The . . . 36
Reavell-Fahie Ltd. 28
Renold Chains Ltd. . . . . —
Research & Control Instruments Ltd. —
Richardsons Westgarth & Co. Ltd. . 14
Robertson, W. H. A. & Co., Ltd. . 13
Rust-Oleum Corporation . . . —

Continued on page 88

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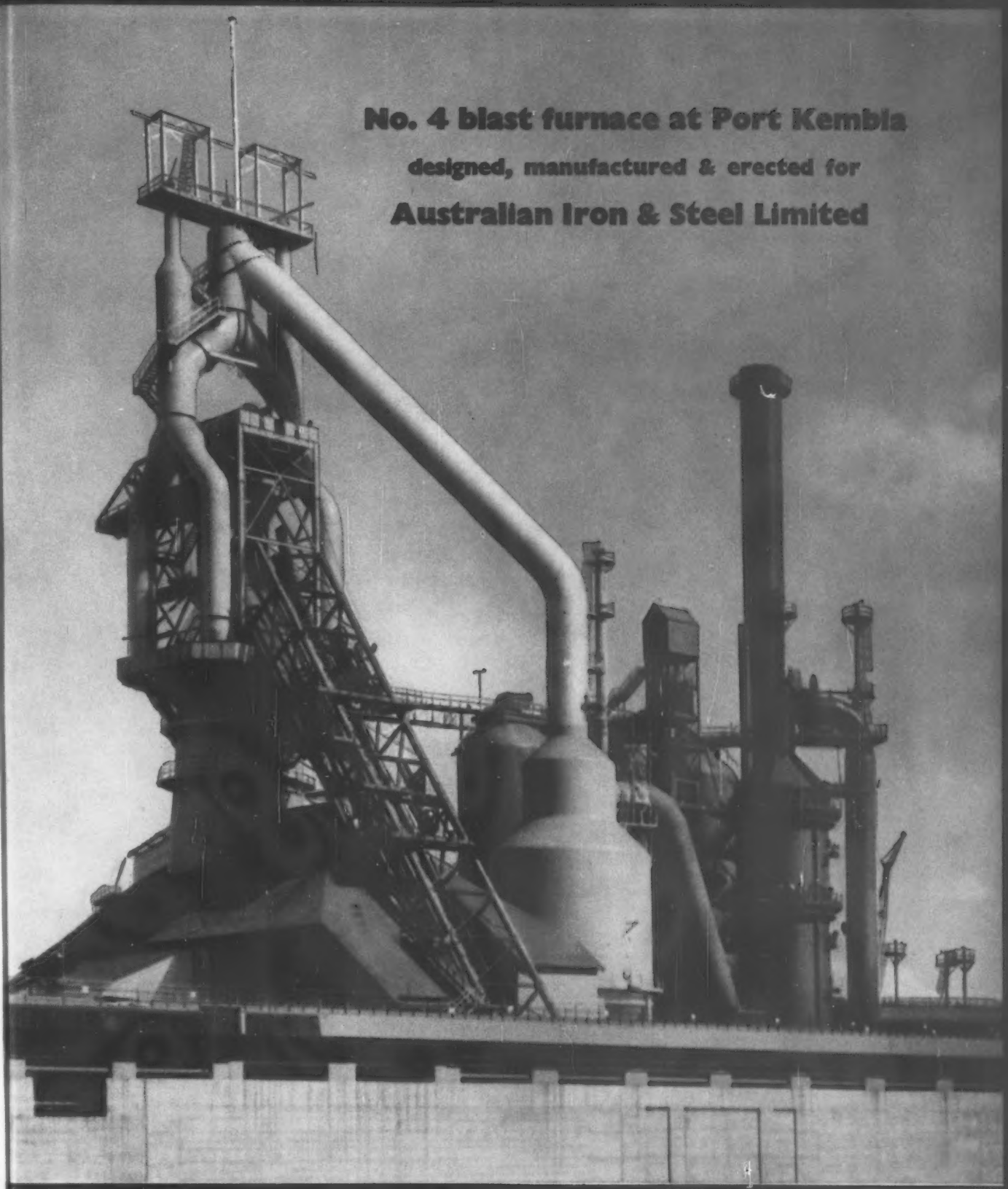

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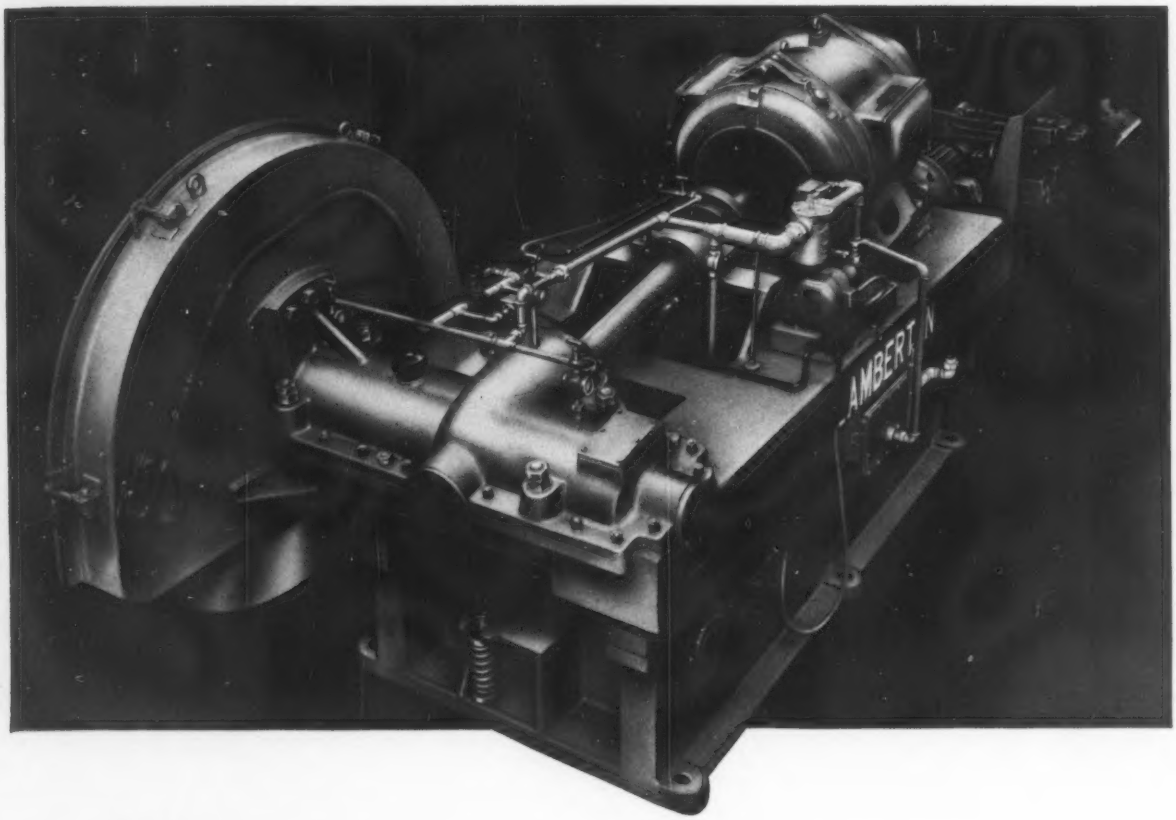

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